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Brown

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LECTURES ON THE ATOMIC THEORY

AND

ESSAYS SCIENTIFIC AND LITERARY

BY SAMUEL BROWN

VOL. I.

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TO
ISABELLA SPRING BROWN
AND
SAMUEL BROWN
FROM THEIR MOTHER.

P R E F A C E.

THE chief reason for publishing these volumes is, as it ought generally to be with all books, the belief that their contents will be found to be of public interest and concernment—that they are pleasant to the taste, and good for food. The other and more private reasons are, the earnest and repeated solicitations of friends, and a sense of justice to the memory of their gifted author, as a man of science and of letters. The best thanks are due and gratefully paid to Mr. Kennedy and Mr. Chapman, for their kind permission to reprint the articles from the *North British* and *Westminster Reviews*. The Sonnets are added, not only for their own sake, but as proofs of the co-existence and interpenetration, in the same nature, of an imaginative and a scientific genius.

SAMUEL BROWN was born at Haddington on the 23d of February 1817. His father, whose name-son he was, and whose rare worth he has embalmed in an exquisite monograph which was the solace of his dying and suffering hours, was the eighth son of John Brown, the well-known author of 'The Self-Interpreting Bible,' and 'The Dictionary of the Bible.' Samuel Brown the elder, besides a life of singular industry and usefulness, is likely

to live long after his death, as the founder of the system of Itinerating Libraries. Our author was his fourth son. He was educated at Haddington till 1830, when he came to the Edinburgh High School. He entered the University as a Student of Medicine in Session 1832-33. He went to St. Petersburg in 1837, and returned to Edinburgh in 1838, and graduated as M.D. in 1839. Though distinguished for ability and energy in all his classes, he was more remarkable at this time as being singled out at once by his fellows as a man of the future—as giving certain promise of greatness. During the winter of 1840-41, he lectured in Edinburgh along with his intimate friend, the late Edward Forbes,—*heu nimium brevis ævi decus et desiderium!* He was a candidate for the Chair of Chemistry in the Edinburgh University in the autumn of 1843, and was next and very near the successful competitor—Dr. Gregory. From that time, and for reasons which we do not now enter upon, believing that a fitter opportunity is in store, he retired very much from public life, and gave himself wholly to the one labour of his life,—the realising experimentally his doctrine of the atomic constitution of bodies.

In June 1849 he married his cousin, Helen Littlejohn. This was his greatest earthly blessing; and not the less so, that for some time before his marriage and till his death, seven long years, he was probably never for an hour, except in sleep, free from pain, and often in extreme agony,—his existence being little else than the fulfilling of his capacity of suffering. When in Russia he had typhus

fever, and it is likely he never was sound afterwards, and carried his death within him in the form of an internal disease, necessitating pain of the sharpest and steadiest kind. He died in the full exercise of his intellect and affections, having fought his disease to the last. He has left ample materials in letters and journals for a full expression of his inner life ; but, as in the case of his scientific doctrines, the time for them is believed to be not yet come. When they do appear they will show, better and more than even the remarkable remains now published, the peculiar form and pressure of his mental and moral lineaments. He died at Edinburgh, in the 39th year of his age.

As has been already said, this is not the place or time, and the writer is not the person to adjudicate upon Dr. Samuel Brown's claims as a primary scientific discoverer.* Time and the hour, which bring the sun up into the heavens, will doubtless bring him likewise into his just place.

But we cannot help recording our unvarying confidence in the speculative truth of his doctrine, and his own solemn assertion of this, with his dying hand, in his private journal ; and though we speak as unlearned, we must affirm our original conviction of the essential truth of his doctrine of the unity of matter, and consequently

* The reader will find in the *North British Review* for November 1856, a paper on Dr. Brown. Until an ampler Life is given, this is all that could be wished, both for what it does, and for what it does not say.

of the possible, and it may be proveable, transmutability of the so-called elementary bodies.

If we believe that matter and all created existence is the immediate result of the will of the Supreme, who of old inhabited His own eternity and dwelt alone ; that He said '*Fiat !*' *et fit* ; that Nature is for ever uttering to the great I AM this one speech—'THOU ART !'—is not the conclusion irresistible, that the Will that matter be, as it must partake of the absolute unity of its Author, resulting in an external world, and, indeed, in all things visible and invisible, is, in any essence which it may be said to possess, itself necessarily ONE, and is by the same infinite Will made what we find it to be, multiform and yet one ; in a word, matter, when first willed, must have the unity of its Author :—

'One God,—one law,—one *element*.'

If, therefore, Dr. Brown's doctrine of the transmutability and unity of matter be established, the *relevancy* of which, to use Dr. Chalmers's happy expression when thanking Dr. Brown in the name of his audience in 1843, may be held to be already proved, it will be to the science of the molecular constitution of matter as much as, and perhaps more than, was Newton's doctrine of gravitation to the celestial dynamics. All this, however, is now left as its herald left it, to time and the workers now or yet to be in the field.

It would be impertinent, and, indeed, it would not be possible to indicate to any one who never saw him, or heard his voice, and came under the power of his per-

sonality, in what lay the peculiarity of Samuel Brown's genius ;—all who knew him, knew it,—none who did not, can. He was not so much cleverer or deeper than most men,—he was quite different ; it was as if a new flower had grown up, which no one ever before saw, and which no one looks for again. His letters and his journal, and above all, his living voice and presence, could alone tell what was best in him: there was a swiftness and a brightness about his mind and its expression, such as we never before witnessed ; its penetrative, transmuting power seemed like that of lightning in its speed and keenness. With this brightness, and immediateness, and quickness of mind, there was great subtlety—a power of clearly expressing almost impossible thoughts, of working upon invisible points, which was quite marvellous.

It is therefore difficult to speak of him without paradox and apparent exaggeration. To borrow an illustration from his own science, his mind was molecular or atomic in its movements and action, atom upon atom, rather than mass upon mass. We would have expected the convolutions of his brain to be deeper, finer, and more numerous than is common.

Add to this, a venatic instinct for first principles, a sort of pointing at them as a dog does at game ; ‘that instinctive grasp,’ as has been finely said, ‘which the healthy imagination takes of *possible* truth ;’ and along with this a hard, remorseless logic, and a genuine love and practice of *method* in its Coleridgian sense, as distinguished from *system*. We do not say all these quali-

ties are to be found in their full development in these volumes ; it would be unfair to them and unjust to him to say so ; but they were in himself, and in his words.

How pathetic to think that this intense and bright nature—

‘ Appearing ere the times were ripe ’—

should so ‘ soon come to confusion,’ that he should suffer as he did, and die with little else fulfilled but pain—his hopes withered, his secret purposes broken off, his years unaccomplished, fame and a great place in the world’s history merely seen from under the opening eyelids of the morn, and then vanishing away ; his sun going down while it was yet day ; the tree of mortal life withering in all the leaves of his spring,—all this is strange and sad ; but what in this world has not in it something both sad and strange ? In things that are past we are optimists, for the plainest of all reasons—that such is the Supreme Will.

‘ All is best, though we oft doubt
What th’ unsearchable dispose
Of highest wisdom brings
About, and ever best found in the close.

‘ His servants he with new acquist
Of true experience from this strange event,
With peace and consolation hath dismissed,
And calm of mind, all passion spent.’

J. B.

23 RUTLAND STREET.

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CRITICAL LECTURES

ON

THE ATOMIC THEORY.

[ANY republication of the papers of Dr. Brown would be imperfect, which did not include the statement, from his own pen, of that atomic hypothesis, to the experimental elucidation of which his scientific life was devoted. To meet this requirement, the Critical Lectures on the Atomic Theory, delivered in Edinburgh in 1843, have been selected, as embodying the completest exposition of that hypothesis, in its historical as well as its practical relations; and to these have been appended whatever notes from other manuscripts could aid toward the further illustration of the subject.

These Lectures labour under the disadvantage of not having been corrected, or otherwise prepared for publication, by the author himself, and of having been drawn up and delivered at a comparatively early epoch of his career. Had they been revised by himself, expressions would undoubtedly have been in some instances modified,

and one or two illustrations rejected, as deprived by later discovery of the specific significance assigned to them. It has not been thought advisable to interfere with these, otherwise than by indicating in notes where it is believed such modifications would have been made. But the hypothesis, as expounded in them, subsequently sustained no essential, or even important, modifications in his own thought. The lectures themselves, as literary exercitations and scientific expositions, received the strong approval of one of the most remarkable and fully qualified audiences that could anywhere have been brought together by such a theme; and the clear and rigid judgment of Sir William Hamilton, to leave unmentioned hardly inferior names, pronounced the lecturer, on the ground of the hypothesis then enunciated, entitled to take his place in the small band of the true discoverers.

Had strength and life been given to him, few who really knew Dr. Brown can doubt he would have extorted from all recognition of his title to that place; would ultimately, despite all the difficulties he had to encounter, and the disadvantages he had to contend against, have established his views on the basis which all can appreciate—that of experimental illustration. This he was not permitted conclusively and finally to achieve, at least in such a form as can at present be laid before the scientific world. The hypothesis is therefore now given forth in its simply speculative aspect,—though as a speculation profoundly in harmony with all our present knowledge, eminently pregnant with practical suggestion toward experimental research and discovery, and pouring a flood of light into at least the *possibilities* of that realm of atomics, where all as yet seems incoherence and mystery.

It may aid the general reader in more distinctly following Dr. Brown's conception, to state in apposition, as briefly as possible, the fundamental principles of the Atomic Theory as at present received, and those by which his hypothesis aims to supersede or modify them.

According, then, to the existing views, atoms, for the purposes of the chemist, are conceived of as solid nuclei, centres of attractive and repulsive force ; not in actual contact, but placed at distances immeasurably small, not only absolutely, but relatively to their own dimensions, whence their shapes, sizes, and mutual actions and reactions, interfere with all possibility of calculating their forces or movements ; the sphere of chemical combination between two heterogeneous atoms—an oxygen and a hydrogen one, for example, combining to form water—being identical with the sphere of gravitative or cohesive attraction between equal and similar ones, and therefore no *tertium quid* can arise from the cohesion of equal and similar atoms, other than that represented by the smallest possible *mass* of oxygen, as distinguished from the two *atoms* of oxygen which constitute it.

According to Dr. Brown's hypothesis, atoms, for the purposes of the chemist, are to be conceived of as extended substances, which can no more be described as solid than as liquid or gaseous, seeing all these three states are equally modified conditions of their aggregation ; centres of attractive and repulsive force ; situated at distances as measurably great, relatively to their own dimensions, as planetary and astral distances are relatively to the unit-masses of planets, suns, and stars ;—whence their forces, movements, actions, and reactions, though subsensible, are conceivably within the power of mathematical induction and geometrical calculus as strictly as are those of the supersensible or heavenly

masses ; their spheres of chemical combination distinct from, and interior to, those of mechanical or gravitative cohesion, and therefore the production of a true *tertium quid* by the chemical combination of two equal and similar atoms is conceivable, and shall ensue, if this hypothesis represent the truth of nature.

For the reasonings by which Dr. Brown elaborates the view now stated, and brings it into practical relation with the concrete details of the science, the reader is referred to the Lectures themselves.]

LECTURE I.

IN the mathematics as well as in applied logic itself, the definition *is* the object of study and subject of relationship: 1, 2, 3; a right angle, a circle, or a parabola. In those mixed sciences, which alone are commonly called natural philosophy, and that only by courtesy, the definition *is* the object for the speculative element of the applied propositions of such perfect sciences, and only describes or represents it for their practical element. A lever is 'a line revolving on a fixed point' for the purposes of *a priori* speculation on the laws of leverage, and 'a beam turning on a pivot' for actual experimentation in quest of *a posteriori* ratification of such laws as are embodied in the mechanism of the sensible world. In the simply natural sciences, in which observation and the classification of many observations under the smallest attainable number of common terms are unaided by the application of the mathetic method, the definition merely represents the object: the scientific definition of a mineral, vegetable, or an animal consists in the tersest methodical statement of all those particulars in which it differs from every other form, and the implication of those in which it agrees with some ascertained class and classes of forms. I say, the scientific definition of a mineral; for, except in the purely classific sciences of natural history proper, this

appropriate method has not yet been fully imparted. For example, if the fifty and more apparent elements of the chemist were described after the manner of the true naturalist, much unnecessary labour would be saved both to the teacher and the student, far more lucid conceptions would become prevalent, and the most striking analogies of contrast and resemblance would lie unfolded before the very eye on a single page, instead of being scattered and hid among the disorderly leaves of a big volume. The same beautiful method should be resolutely applied to the multitude of compound forms; the crowd of daily accumulating substances demands the Herculean labour; and surely some Linnean mind will soon appear, render the statics of chemistry the natural history of atoms, and furnish us explorers with our chart. The processes for the preparation of the elements and their compounds are best given in diagrams or symbolic equations. Manipulation cannot be taught by books, except they be as thorough and purely technical as the works of Faraday and Rose, and even these are useless out of the laboratory; so that the plan which has just been suggested in connexion with the consideration of the value of definitions in the simply natural sciences, would at once abbreviate and dignify the study of chemistry as a science. The constitutive definition of the mathematics is absolute and independent. The postulative definition of the applied sciences is feigned for the purposes of investigation; while the representative definition of the unmixed sciences is contingent, and consequently fluxional as well as always imperfect.

Definitions of the third of these kinds represent either actual observations, or general views of at least two such; and as the scope of observation is limited by the position of man on a planet and the short reach of his senses,

while all mere generalisation is consequently partial and progressive, the definitions of such observations and generalisations are necessarily still more imperfect and processional. Hence the sure and successive overthrow, or rather absorption of theories, as the sphere of concrete knowledge becomes enlarged or illuminated by new discovery; and the theories of the natural sciences are valuable almost only as indices of their advancement in the course of time.

Accordingly,—to pass by the Greek Physicists with the monadon of Demetrius, the homœomera of Democritus, and the elementary quaternion usually ascribed to Aristotle; the Polypharmists of Arabia with their mercury and sulphur for the common constituents of all the metals; and the Alchymists of middle-age Europe, who united the doctrines and somewhat of the characters of both,—the definition of modern chemistry has undergone as many changes as the science itself has passed through, from the time of Nicholas Le Fevre till to-day. Arnoldus de Villâ Novâ had, early in the thirteenth century, drawn the notice of the adepts to the varied volatile products of the destructive distillation of bodies, having himself described spirit of wine or aqua vitæ, and oil of turpentine or oleum mirabile, while he was the author of one of the most celebrated receipts for the philosopher's stone. Raymond Lully, his pupil, had followed this direction with success, and discovered a mixture of nitric and nitrous acid, that aqua fortis, the solvent power of which over the most obdurate metals and minerals persuaded some that the Alcahest had been found. Basil Valentine had, at the beginning of the fifteenth century, driven the *Currus Triumphalis Antimonii* with so much tact as not to have taken one positively false step in showing the process of the metal

from the ore to the reguline condition, and from the regulus to the calx again, although he held by the four elements, and hinted the possibility of separating the quinta essentia of the four, and all their modifications in the Protean multitude of sensible forms. And lastly, Paracelsus had, a hundred years after both, professed to have extracted the quintessence as the elixir vitæ, and taught his disciples to despise the schoolmen as well as the Arabians; when Le Fevre, a man of practical understanding, and a very sceptical temper, took the first decisive step in positive analytical chemistry, about the time of the foundation of the Tuscan Academy, the Royal Society of London, and the Parisian Royal Academy of Sciences.

Wood, decomposed by combustion in the air, yielded the Aristotelians flame or fire, smoke or air, moisture or water, and ashes or earth; the four elements, and the products of a genuine analysis. The doctrine built on this analysis is the starting-point of chemistry in history. It is the first methodical reflection on observed facts of analysis; the germ of our science; and so we may have done with the vain discussions on its origin. Why, if chemistry be considered as an art, as the art of changing sensible forms by operations affecting their intimate structure, then not Hermes Trismegistus, nor Maria the Jewess, as she is called, nor Moses, nor the daughters of men to whom the sons of God came down, and in the impotence of passion betrayed the secrets of the sky, nor yet Tubal Cain, but Adam himself must be regarded as its father as well as ours. Chemistry is a contemplative, though yet only a practical, science; and the proposition of the four elements on the basis of this analysis of wood by combustion in the air is the salient point of all its course. It is curious to think that the most recent method

of analysing vegetable fibre, invented by Gay Lussac and Thenard, and improved by Liebig, is essentially the same as this of the Epicureans. Le Fevre, however, decomposed wood by destructive distillation, just as they do now-a-days in our manufactories for the extraction of vinegar, and he procured water, an acid spirit and an oily liquid in his receiver, while smoke escaped and charcoal remained in the close apparatus in which the analysis had been effected. The last substance burned in air gave fire and ashes, so that from the original wood there had been produced six ingredients instead of four ; and the very analysis of the schoolmen was shown to be imperfect. Everything else soon follows ; the ash is decomposed by the dissolving power of water into salt and earth ; sulphur, mercury, and arsenic appear to be as elementary as any of them ; the only proof of an element, indeed, is the fact of its yielding nothing else to analysis ; there is no limit to the number of elements ; and the very metals or their calces may be as infrangible as they all. On grounds and dim conjectures like these did Le Fevre maintain that chemistry is not the doctrine of the four elements, nor the science of mixts, nor yet the art of transmutations ; but the art of analysis with a view to discover the numerous ingredients of all kinds of matter, embracing in its scope every attainable form which God has brought out of chaos by creation. It was not, however, till Barchusen had introduced the term *affinity* to express the germinating conception of a dynamics for our science ; and Boerhaave defined and fixed it in the language of chemistry, that a definition, combining the dynamical with the statical element, could be framed.

There are just three great factors, in the first class of men, of the history of what is properly called modern

chemistry,—Stahl, Lavoisier, and Dalton. For Stahl the definition of chemistry was little more than it had been for Le Fevre, although he did the noble service of giving the chaos of known facts about the composition of bodies cohesion, shape, and transparency, around a far-stretching hypothesis, which not only sufficed for all the wants of the science during a space of sixty years of rapid progress, but did really represent the truth of nature in an inverted image like that of the *camera obscura*. Scheele, Priestley, Black, and Cavendish, did no more than work out the systematic thought of Stahl, but that with so much success as to render the circle he had drawn around them painfully too narrow, and to demand the appearance of some Lavoisier to disenchant them, and give them such enlargement as their own discoveries required. Lavoisier did his work so well, spite of so much opposition and disbelief, so patiently, so completely, and at last so triumphantly, that all the world of science is aware of the magnitude of the obligations under which he has laid it; and in a flying sketch like this we must not dally with even so attractive a theme. Suffice it that,—having reversed the doctrine of his predecessor, Ernest Stahl, and proved the metals to be simple, and their calces to be composed of the metals and that oxygen or vital air which had been previously discovered by Priestley and Scheele; having laid the phantasm, phlogiston, for ever to rest, and announced a positive theory of fire; having once for all proclaimed the sceptical definition of an element as merely that which has not yet been decomposed into simpler forms; and having, more clearly than any one since Le Fevre's revolution, descried the momentous indication that the deeper the chemical analyst penetrates from the surface of nature, he converges the more till he reach a

comparatively small list of elements, perhaps to be lessened and lessened till only two should remain intact,—he and his immediate followers proceeded to define the science itself with something like precision. Stahl had said that “universal chemistry is the art of resolving mixt, compound, and aggregate bodies into their principles, and of composing such bodies from those principles;” but added, that a simple body “has no physical parts,” *i.e.* is indecomposable, as well as not yet decomposed. Besides, for all the clearness of his tenet that the metals are compounds of their calces with phlogiston, his notions of the nature of the calces themselves were far from lucid, inasmuch as he clung with fond idolatry to the opinion of the wayward Beccher, that there are only two elements of all things, *water and earth*. Nay, he was fain to believe with Van Helmont, that water is transmutable, by long-continued boiling, into earth; that there is only one true element,—water; founding on an experimental error, which was not to be detected till Lavoisier had occasion to raze both the false and the half-true of temporary systems to the ground, in order to the erection of a stabler and nobler structure out of the ruins of the old, on a new foundation of his own. How crystalline his conception of the object of chemistry as the science of the constitution of bodies! In the *Traité Élémentaire*, which the enthusiastic and too Gallic Dumas calls the very gospel of the modern chemist, these transparent sentences occur, although there is no formal definition in the work: “Chemistry, then, marches towards its goal, and towards its perfection, by dividing, subdividing, and subdividing still again; and we know not what shall be the termination of its success. We cannot, then, be assured that what we regard as simple to-day is so in reality; all that we

can say is, that such or such a substance is the actual termination of chemical analysis, so far as it goes, and that it cannot be subdivided any further in the present state of our knowledge." In the light of so intelligible a principle, the value of which no man can ever feel till he study chemistry upwards in history, Lavoisier proceeds to state his opinion, that "the earths shall soon cease to be counted in the number of simple substances," and that their "indifference for oxygen," as he calls it, is owing to their being already oxides—a conjecture which it was reserved for our own Davy to realise, as everybody knows. Fourcroy, the eloquent and methodical disciple of Lavoisier, is always classifying and defining, as is natural to the early friend and follower of a great original, who left that part of his work unfinished. In the *Système des Connaissances Chimiques*, chemistry is defined as "a science which learns to know the intimate and reciprocal action of all the bodies of nature on one another," the adjectives *intimate* and *reciprocal* being afterwards explained as referring to "molecules, the volume and mass of which cannot be submitted to mensuration and calculation." Davy—far the greatest of the acolytes in Lavoisier's train, and if not the inventor of the method, certainly the foremost discoverer in chemistry by means of electrolysis as a new kind of operation for the dissolution of chemical union—naturally enough describes chemistry as "the science which relates to those operations by which the intimate nature of bodies is changed, or by which they acquire new properties." Berzelius, whose discoveries of facts by common analysis have been more numerous, and whose knowledge of the details of chemistry is more multitudinous than that of any man alive, describes it as "the science which makes known the composition of bodies, and the manner in which they

comport themselves with one another." In fine, considering the facts of catalysis ; and that attempt to determine the mode in which components arrange themselves in given classes of compounds which originated with Davy, and has found its consummation in Liebig, chemistry may now be defined more comprehensively still even in this *a posteriori* manner : " the aim of chemistry is to discover the composition and the constitution of compound bodies, and explain all such mutual reactions of sensible forms as end in changing the composition or constitution of at least one of the agents in each case."

In the series of definitions, implicit and expressed, which we have glanced at from Le Fevre to Berzelius, there is a principle of development. Each takes in that which goes before,—the latest comprehends them all,—another will supersede it in turn. If the professed discovery of the isomerism of carbon with silicon were once admitted, a deeper and wider definition would not be far to seek. Dating, however, from Beccher, the teacher of Stahl and author of the *Physica Subterranea*,—a work which his more illustrious disciple fondly blazoned to the world as the *opus sine pari*,—there has been nothing revolutionary in the evolution of modern chemistry yet ; and there shall be none without the certainty of destroying something true. That was a revolution, indeed, which Paracelsus began, and Van Helmont, Cassius Libavius, Glauber, Agricola, and other practical men without a thought advanced ; which was sagaciously consummated by Le Fevre and Lemeray, and ended in the modern chemistry. But, at the risk of standing alone, I assert that Saxon Europe did, notwithstanding its great gain, also lose a great idea of the old Greek world at that very time ; as we shall find before these lectures are done. In the wholesome development of science

every step gracefully follows another, and every movement is as organic and alive as in embodied nature herself. Sciences grow like trees. The purely speculative are endogenous, and swell outwards from within, like the palm, stretching the fingers of its leaves to heaven ; the unmixed practical are exogenous, and ring succeeds and embraces ring every propitious year, like the spreading oak which shades the land and furnishes timber for the sea ; and the applied combine the nature of both.

From such reflections it is evident that, so long as the definition of chemistry shall continue to be merely representative, another more exact, and at the same time more comprehensive, may be expected to carry within it that which suffices for any given time before the progress of discovery. May a perfect definition not be eventually constructed for chemistry then ? ONLY ON ONE CONDITION, —that it be formally admitted within the pale of those mixed sciences, the definitions of which, both specific and general, are practically representative, but speculatively constitutive, as in astronomy, optics, and mechanics. A hypothetical premiss regarding the intimate nature of those natural objects with which the chemist converses, must be assumed in order to the construction of a philosophical definition. The more abstract the premiss the higher the definition, and the more the premiss is the literal translation of manifold sensible facts, the more useful the definition for new discoveries. The hypothesis may be so abstract as to render the definition next to universal, and yet so closely fitted to the sensible facts as to admit of a definition suited to the most particular instances. Both premiss and definition, however, must be held and wisely used only as a fiction of methodology, framed for the purpose of philosophical

illustration of science, but more especially of investigation according to the triumphant applied method of astronomy. And this, even though the presumptive evidence should be overwhelming; for there belongs to the real matter of philosophy no proposition which is not demonstrable by universal canons, and none to that of science which is not directly transferred by generalisation from the page of nature itself, which is open to us all.

Such a hypothetical premiss for chemistry is the atomic theory of Dalton, although he has not himself asserted it as such. In truth, it requires to be stated as the postulate of the molecular, or, to employ the far better term of Democritus, the homœomeric constitution of sensible forms, before it can be made available. For the venerable and revered discoverer of the law of equivalents, the first of men who have ever cultivated our science, atoms are indivisible *nuclei*; a conception which neither reason sanctions nor nature will acknowledge. Corrected as it has been by Turner (who was cultivating his fine intellect by the study of the higher mathematics for the express purpose of infusing some mathetic element into the methodology of his favourite science, when he died), the atomic theory, whether it be literally true to nature or not, meanwhile serves to consolidate the facts of chemistry, and render them intelligible to a considerable depth, while it does certainly figure the *forces*, abstractly contemplated, which work in the production of chemical phenomena. Nay, this is the only lawful view of the atomic theory; and it will be found that, placed in this light, it affords a secure and perspicuous foundation for the erection of constitutive definitions of the objects of chemical study, viz., chemical equivalents, after the manner of Newton and Boscovich—a work which has been attempted of late years, indeed, by Mr. Exley, a Fellow

of Cambridge, and Professor Mosotti of the Ionian Islands.

The atomic theory of matter is the hypothesis that each sensible form (a crystal, drop, or breath of air) is made up of homœomeric parts, not essentially indivisible, but indivisible by such forces as are competent to the division of their aggregates. These parts are called particles, molecules, atoms; the last name being objectionable on account of its etymology, but the most convenient, when used as a name without reference to its derivation.

This hypothesis supposes, for instance, that a piece of sulphur may be mechanically divided and subdivided till it shall be all broken up into a multitude of equal particles, incapable of further subdivision by such forces as have thus far divided the piece, and possessing all the properties of the piece except such as resulted to it from their own coaggregation in its form; solidity, fusibility, volatility, yellowness and others. This illustration implies that an atom is neither solid, liquid, nor gasiform; a corollary of great importance to the definition of special atoms, say an atom of carbon, for the purpose of speculative investigation.

Again, particles of oxide of hydrogen are indivisible by such operations as divide water, the sensible form which is produced by the coaggregation of a multitude of particles of oxide of hydrogen into quantities greater or less; but no sooner are particles of potassium presented to water, than it surrenders two kinds of particles, hydrogen and oxygen. The aggregation of many hydrogen atoms produces a sensible form different from that which results from the aggregation of many oxygen particles; and both of these differ from water. It is deducible from this illustration, that masses represent atoms; different masses, different atoms. This is the

conception of combining volumes and equivalents, and the hypothesis of atomic weights and volumes.

Once more, atoms of sulphur, oxygen, and hydrogen, indivisible by forces which divide bulks of these substances, apparently indivisible by forces like that of potassium acting on water, may yet be divisible by a third and yet unknown manifestation of analytical power. Chemical analysis, as now known, failing to resolve the so-called elemental atoms, another force is to be diligently sought, unless the mind be content to think that, in a mechanism where all is simplicity of design and superstructure, there are at least fifty-five, and likely far more, material bases. A new law of constitution may begin at the line of the elements, just as that of chemical composition succeeds that of mechanical aggregation, beginning with the more complex atoms and ending with the elements. This appears to be the opinion of Dumas, the finest genius now cultivating the science. This is introduced, however, solely as an illustration calculated to bring into stronger relief the conception of the atomic hypothesis.

Such, then, is the hypothesis in question. It cannot be demonstrated, nor is it a literal theory of facts. It must be taken as a postulate to be worked as an unknown quantity in the equation of the science. Rightly followed out, it can never conduct to error, and it may to very great discoveries, as it has done already ; but whenever it shall be regarded, *on its present foundation*, as anything more than a hypothetical premiss which gives coherency to every ascertained fact, and affords a salient point for inquiry, it may as readily seduce to impracticable speculation ; and the tragedy of Swedenborg shall be re-enacted for the amusement of the practical and the difficult edification of kindred natures.

Hypothesis though it be, however, the presumptive evidence for this doctrine is so vast in extent and weighty in force as to constrain the opinion, while it does not compel the belief, of every one who considers its admirable fitness to explain the phenomena of general physics and chemistry, and wisely ponders the chaos into which these sciences would rush down, but for this binding and illuminating centre of attraction and light. The evidence of this atomic proposition, indeed, is the same in kind,—although it shall never be the same in degree, till the mathematics shall have been applied to the elaboration of its consequences,—as that of the dynamical postulate of the modern astronomy,—that the same law of attraction is expressed by the motions of the heavenly bodies, as is found by experiment at the surface of our globe. In both cases the hypothesis is assumed, observations are made at its suggestion, and its adaptation to the truth of Nature is more and more strikingly exhibited by the cumulative testimony of facts every day. In truth, so far as the doctrine of atoms is concerned, no formal proof can be given, or need be sought (any more, and not any less, than in any department of natural science whatever); the metaphysical argumentations on the subject, which have been so wearily repeated for centuries, being sophistical transferences from premises regarding space, to conclusions regarding matter. Myriads of things cannot be explained without it; but that is no proof, for sovereign Reason, the only lawgiver in nature, despises everything short of boundless and absolute dominion. Only the more numerous, diverse, and significant the facts that are rendered comprehensible by the understanding, the nearer does the accumulation of presumptive evidence mount to the altitude of proof. Is this,

then, the place to review the multifarious objects and phenomena which the homœomeric doctrine of sensible forms hypothetises, in order to see how abundantly it illustrates them? No. This has been too often done in the history of science,—this application of the hypothesis to the facts, as soon as the hypothesis has been itself defined. Why, the hypothesis of the Epicureans explained all that was known when it was framed, and Dalton's is sufficient for all the purposes of chemistry so far as it has yet come; yet both are charged with error, which we shall find to have now become impedimental to the progress of atomic science. Phlogiston explained all the well-ascertained facts regarding the reduction of metals, yet was false; and any hypothesis may very well adapt itself to the known truth of nature at a given time, yet be fundamentally erroneous, and therefore unfit for the future necessities of science, especially for the consummation of science by the mathematical method. The first thing to be determined about a hypothesis, after its clear definition, is its logical legitimacy. Is the atomic doctrine a legitimate use of the philosophical hypothesis? For me this inquiry must be answered in the affirmative, before I will even entertain the doctrine with any hospitality, because it is surely time to have done with provisional theories; and, having pondered the fate of the science through all its varying phases of metaphysical physics, polypharmacy, alchemy, and modern chemistry, I have observed, that from Geber down to Graham, the men who have gloried the most in the practicality of the science in their hands, have always been the most addicted to mistake temporary for everlasting hypotheses; and I am weary of imperfection.

The philosophical hypothesis in physics has two

species. The one consists in the entertainment, for purposes of investigation, of *that*, as the cause of an unknown phenomenon, which is known to be the cause of analogous phenomena ; or, to state it in reference to matter in space, it is the entertainment of the conception of such things, for the constituents of an object insusceptible of sensible analysis, as are known to be the constituents of analogous objects. The other is the acknowledgment of an abstract conception as the sign of a concrete ; and that, more strictly than even in the former case, for the sake of research—viz., for the purpose of reasoning provisionally from the universal to the specific. The former is inductive, and for the understanding, while the latter is abstractive, and becomes an object of reason. As illustrations of the former, may be adduced Franklin's supposition of the identity of lightning and thunder with the phenomena attending the electric discharge ; and Ampère's conjecture that calcium, and fluorine, the universal solvent, are the constituents of fluor spar. The applied sciences are full of instances of the latter. Sun-light is a cone of points projected in lines diverging so little that they may be dealt with as parallel, and so on. The difference, in fine, of the two species, may be exemplified with direct reference to the present subject, thus : The homœomeric proposition ought to be viewed as an inductive hypothesis, and, this taken for true, the assumption that an atom may be reasoned about under the fictitious form of "a point, the ultimate repulsion of which is infinite," would be a hypothesis of the second kind. It is with the former we have to do at present, although we shall have to discuss the latter too some other time.

The only anticipatory test of the legitimacy of this kind of hypothesis is that it be what has been called

possible. It must be *possible*: and the only criterion of possibility in natural science is the analogy of what is known; the more radical and comprehensive the analogies, the more trustworthy the inference. This is not the place to discuss the law of analogy; and the criterion under review is more easily illustrated than defined. The doctrine which refers the phenomena of heat to caloric supposes that, the like of which we do not know to exist in nature at all,—a form of matter without weight. This imaginary imponderable is conjectured to cause the expansion of the ponderables, whether solid, liquid, or gasiform; so that it is not itself solid, liquid, or gasiform; for if gasiform, to what does it owe its elasticity, since the gases are imagined to derive their dilation from caloric? This hypothesis of the phenomena of temperature is thus trebly impossible, according to the only criterion of natural possibility. The vibratory doctrine of light may be contrasted with it, at least so far as that doctrine regards light as a phenomenon, and not an entity. It is at least, and independently of everything else, a possible hypothesis. Light is manifested by certain actions excited by some external cause on a nerve of special sense—the Optic and its expanded retina; and Sound, by analogous actions on an analogous nerve—the Auditory. Now, it is known, that those actions in the latter instance are proximately effected by aerial vibrations; and the transference is possible and natural to the conception of the oscillations of either ærial or ethereal particles as the cause of light.

In answer to the inquiry regarding the legitimacy of the atomic theory as a hypothesis of the constitution of sensible form, it is unnecessary to consider the doctrine of atoms, as received among the Epicureans, and stated

by Dalton, inasmuch as it is clearly erroneous on the score of natural impossibility. It supposes, as the components of sensible matter, what are not known to be the components of any analogon of sensible matter, viz., indivisibles; as well as implies the conception of solid central nucleuses, which is incongruous with the conception of solidity as itself a property of form, derived from the coaggregation in a specific manner of many atoms.

Once let the proposition be stated in that amended form which has been impressed on it by modern chemistry, and atoms be defined as indivisible by such forces as divide their aggregates or the forms produced by their concurrence; and the hypothesis becomes grounded on analogies more manifold and stupendous than any other in the compass of the sciences. Notwithstanding certain fanciful illustrations by Pascal, Howe, and other sublime authors, the subject has never been contemplated on any such foundation as is now referred to; and I will urge it at some little length and then have done for the day.

The analogy on which I mean to assert the logical propriety of the homœomeric doctrine as naturally possible, is the profound analogy which subsists between chemistry and astronomy, of which sciences each is visible by reflection in the other. It is difficult to unfold this thought in the way of ascending induction of particulars, and I beg you to let me lay down my positions in the form of some dogmatic paragraphs resting on the assumption of atoms; so that, the analogy failing, the assumed premiss shall fail also, so far as the pretended analogy is concerned.

I. Astronomy is the science of the supersensible or heavenly bodies, meaning by the phrase those parts of which the firmaments of the sky are aggregates, and of which solar and planetary systems are *tertia aliqua*;

parts known to be in themselves divisible, never divided in the astronomical operations of nature, probably indivisible by such forces as may divide their aggregates and *tertia aliqua*, and not visible in perspective by reason of their magnitude and distance. Chemistry is the science of the subsensible bodies or atoms ; meaning by the phrase those parts of which the sensible forms of the earth are aggregates, and of which more and less compound molecules are *tertia aliqua* ; parts not known to be essentially indivisible, never divided in the chemical operations of nature, indivisible by such forces as divide their aggregates and *tertia aliqua*, and not visible, individually, by reason of their infinitesimal dimensions and proximity. The differences with distinction of these two definitions are manifestly referable to the accident of man the definer's position among the worlds.

II. Astronomy is twofold, its objects being contemplated both as existing variously combined in space, and as agents in events taking place in time. Statical astronomy discovers what celestial bodies exist, and in what combinations they exist ; and dynamical astronomy determines the phenomena in which these bodies bear their parts, and what parts they bear. The former observes the earth and moon, and that by combination they produce the terrestrial system ; Jupiter with his satellites, and that they constitute the system of Jupiter ; the sun, planets, satellites, and comets, the several ingredients of that vast unit—the solar system, which, again, enters into the composition of our firmament ; a fabric which, how magnificent soever to apprehension, does in reality sustain no more comparable a proportion to the world of firmaments, than the compound molecule of a crystal salt to the mass which is the product of its indefinite aggregation. The latter eliminates from

observations the laws expressed by the motions of these, and traces the causes and effects of such movements.

In like manner is chemistry twofold. Statical chemistry discovers what atoms exist, and in what combinations they exist. The dynamics of the science should explain the phenomena which atoms concur to produce, and determine the share of each in the production of these phenomena. The former analyses all kinds of compound atoms, a compound atom being an atomic system, or more than one atom acting in time upon other atoms (simple or compound) as a unit. The latter should read the laws of the motions of atoms around each other, and interpret the causes and effects of such mutual movements. Moreover, atoms are so inconceivably little, that their aggregates or sensible forms are the ostensible subjects of experiment ; just as those firmaments which the former Herschel discovered existing, and proceeding beyond our own, are contemplated by the astronomer as unities constituted by an unreckoned host of systems. This gives occasion to notice more particularly that contingent difference between the sciences I am now endeavouring to place together as conjugate mirrors, which derives itself from our position standing here on a smaller constituent globe of the solar system, itself only a constituent compound globe of the firmament in which it swings ; we see only a little way around us, and in that little, every world seems far asunder from its neighbours, a separation which is multiplied a thousand thousand times by calculation. But we survey a very universe of atoms, in the shape of a single crystal or a drop of dew ; and that from such a height, that the myriads are to the eye of sense confused in one continuous form ; while the aid of calculation has not yet been invoked to scatter the delusion of appearance.

III. Again, and to descend to a particular instance : As a silver, three nitrogen, four hydrogen, and four carbon atoms are the constituents of a molecule of the argento-cyanide of ammonium, which is their combined sum, in relation to the atomic systems among which it moves *one* and a true *tertium aliquid* ; so the sun, his planets, their satellites, and the comets, are the constituents of the solar system, which is their combined sum, and in relation to the astral systems among which it moves *one* and a true *tertium aliquid*. In both these cases are the specific attributes of the constituents merged in the respective results of their productive community ; a stellar system on the one hand, and a saline compound atom on the other. Relatively merged, but within themselves as distinct and individual as before combination ; for as this earth is, to the extent of her constituted character, absorbed in the formation of the solar system, and yet maintains a personal relation to her moon, with whom she constitutes an individual product, and shares in systematically distinct phenomena ; so, while an atom of water plays the part of one constituent of a complex atomic system, say the molecule of some salt, although it meanwhile enjoys no external relative existence, it is still self-contained and self-related, as itself the product of constituents, oxygen and hydrogen.

Such are the analogies of chemistry to astronomy, feebly expounded. As now given, they are more formal than scientific, more abstract than practical ; but the question of the legitimacy of a hypothesis is one of form and abstraction. Accordingly, all that I have attempted at this stage of the investigation is to ground the logical propriety of the doctrine of atoms on the logical analogy which subsists between chemistry, concerning the objects of which the doctrine is hypothetically held, and astro-

nomy, the objects of which are *known* to possess a mode of composition radically analogous to the subsumed atomic constitution of sensible form. The gist of the thing is this:—In supposing atoms as the constituents of sensible forms and chemical compounds, we hypothesise a manner of constitution known to exist in analogous products,—firmaments, and stellar systems; and, consequently, the hypothesis is at least possible. *Q. E. D.*

The resemblances, however, of stars and atoms are far closer and more practical than I now claim, as shall be found in the sequel. In the meantime, this analogy, which I feel to be bursting with suggestions now speculative, now emotional, and again inexorably practical for the uses of the laboratory, will not be deemed unprofitable by those who remember that the dynamics of astronomy is far advanced, and its method perfect, while dynamical chemistry has hardly begun to appear in open day; and who are able, at the same time, steadily to regard the former as the model and measure of the eventual destiny of the latter.

LECTURE II.

It is my earnest desire that these lectures be a series of returning revolutions around one central, yet pervading and organic thought; and, before proceeding to the theme of to-day, I will review the line of curve we have already described, for my own sake, if it be unnecessary for yours.

After some premonitory reminiscences of a general kind on the definitions of the speculative, practical, and mixed sciences, we came down to the definition of chemistry in particular, considered as a science of still unaided induction, and studied the subject historically. Glancing at the composition of European alchemy, touching on the proper labours and general conceptions of Arnoldus, Lully, Valentine, Paracelsus, and Le Fevre, and noticing the dogmas of Beccher regarding the constitution of all sensible things, we examined the first methodical definition of modern chemistry by Stahl, the creator of that admirable phantom, phlogiston; as it is found in the *Fundamenta Chymica*, published at Nuremberg in 1723, and professing to display the foundations not only of the commoner but also *sublimioris sic dictæ hermeticæ atque alchymicæ*. From the speculative yet very practical Stahl,—and I call him so because he wanted only a more advanced state of

the details of the science to have been a speculator of inflexible practicality of character and achievement,—we ascended at once to Lavoisier, a man of thought so lucid and comprehensive, that when we remember what he had to outgrow, and that Scheele, Priestley, as well as Cavendish himself, had been unable not only to do so, but to perceive the necessity of it, we shall gladly confess that chemistry owes to him far more than to any other, always saving Dalton. From Lavoisier's clear conception of the objects of our science, you will remember that we saw unfolding the formal definitions in successive little eras of Fourcroy, Davy, Berzelius, and still a fourth which the progress of discovery authorised us to construct in the name of the chemists of 1840, within the scope of the same germinal thought. The lesson deduced from this rapid historical ascent was, that in the series of these definitions there is a principle of development, each including that which has preceded, the last comprehending them all, and another being destined to unfold the last in its turn. Then came the question, May not a perfect definition of chemistry be erected? And the answer, On condition that it be impregnated with the mathetic method. We then found a hypothetical premiss regarding the nature of chemical equivalents necessary to such a consummation, and proposed the homœomeric doctrine of Democritus, and the atomic theory of Dalton, modified in essential particulars, as such a premiss. Having defined and illustrated the atomic hypothesis, we refused to survey the facts it is constructed to explain, before first inquiring if the hypothesis itself be a legitimate use of the philosophical postulate. Lastly, after discussing the law of legitimacy in such a case, we found that it *is* the legitimate hypothesis, on the foundation of an analogy which I proceeded to

expound at some length between stars and atoms, systems and compound molecules, firmaments and forms; and we are now in a case to survey the facts of observation which have been congregated around the proposition by discoverers, in presumptive evidence that the homœo-meric hypothesis is in reality not a mere conjecture, but the atomic theory a truth of nature.

They may be classed under three heads: There are facts connected with the natural history of sensible forms, or mechanical facts; there are others regarding subsensible forms, or chemical facts; and there are certain astronomical facts, which are rendered comprehensible under one theory by this hypothesis.

Before proceeding, however, to the review of these in their order, it is right to offer a theory of the past history of the atomic doctrine, the bearing of which on the discussion of the doctrine itself, as defined in my former Lecture, will become apparent as we advance.

It would appear that a certain doctrine of sensible matter as being produced by concourse of substantial atoms in opposition to the prevalent idealism of the East, was very early promulgated among the Hindoos—somewhat the reverse of which has prevailed in modern Europe under the influence of Berkeley, Kant, and especially Fichte. If the suspicion of some, that the monads of Pythagoras were endowed with corporeity, be correct, it is probable enough that a similar tenet was discussed by the initiates of the old Egyptian mysteries, and likely in the same antithesis. The atomic theory of the Greeks—as taught by Democritus, the disciple of Leucippus, elaborated by Epicurus into a scheme of materialistic atheism; implied by Anaxagoras in his tenet, that every distinct kind of matter has its distinct shape and weight of particles; not discarded by Empe-

docles in his proposition that all the distinct kinds of matter are the products of different mixtures of the four mutually convertible elements ; somewhat carelessly retained by Plato, who even speaks with complacency of the particles of the quaternion being of different shapes cut out of the *πρώτη ὕλη* ; and contended against by the Stoics,—this theory stood for the most part in opposition, not to idealism, but to a counter-conception, that matter is infinitely divisible. It was in this antithesis, too, that the discussion of the subject was revived by the Cartesians, as well as that Dalton unfortunately allowed it to be placed by more than his first opponents. Of those who have viewed the question in this light, and argued for the infinite divisibility of matter, the staple demonstration has been, that whatever has length and breadth is mathematically divisible, or whatever consists of parts must be divisible into parts ; a thing most true, if that were the way of contemplating the subject. Of the opponents of these, from Democritus down to our own Newton, the constantly repeated argument from nature was this,—That if the particles of which bodies are composed were not indivisible beyond a certain point, they would wax old and crumbling, perhaps cracked, and so the nature of the shapes depending on their agglutination be changed ; whereas water, air, earth, and fire are as full and fair as ever. “Water,” says Newton, “and earth composed of old worn particles would not be of the same nature and texture now with water and earth composed of entire particles at the beginning. And therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles ; compound bodies being apt to break, not in the midst of solid particles, but where

those particles are laid together, and touch in a few points." Every one, however, who was here last Saturday, will at once observe that it is not in this antithesis that the point is to be studied ; but there is still another in which it has turned up again and again in history. Before proceeding to this, it were wrong not to state, as forcibly as possible, too, that Aristotle contended against the conception of the essential indivisibility of Democritus's atoms, while he admitted the probability of matter being composed of particles indivisible, ἀλλ' οὐκ ἐντελεχεία ἀλλὰ δυνάμει, not potentially, only actually. Zeno seems to have been the first to put the atomic theory in the third antithesis, by asserting that material form is the product of unextended repulsive points. Leibnitz's doctrine of monads is essentially the same ; but Father Boscovich has unfolded it with elaborate precision in his wonderful work, the *Theoria Philosophiæ Naturalis*, published at Vienna in 1759. The antithesis is this : One party, with, say Newton, at its head, and embracing the chemists of the present day, so far as they concern themselves about the question,—for hitherto it has had infused into it none of that practical importance which is the very life of a chemist,—maintains that it is necessary to suppose, for instance, that the particles of which water is made up are possessed of solid bulk, else they could not communicate bulk to the form they produce by aggregation ; that the particles of oxygen and hydrogen which compose a water particle must possess bulk, else they could not communicate the property of communicating bulk to the water particles they compose ; and that, of whatever simpler particles an oxygen (or hydrogen) particle be ultimately composed, these ultimate particles must have solid nucleuses. The other party—let us call them a party—see that this is

not at all necessary ; but that if a number of self-repulsive points in limited space be granted, there is at once produced an extended substance. If the central point in that sphere, which a curved hand can embrace, were suddenly endowed with the irresistible power of repelling my fingers through three inches of spherul diameter, it were the same as if a three-inch ball of adamant were thrust into my grasp. The former is the atomistic view of the atomic hypothesis, and the latter the dynamical. The latter is held by Wolf, Carus, Passavant, Schelling, and other modern philosophers ; nay, Newton himself, who defined an atom as a solid nucleus surrounded by spheres of attractive and repulsive force, seems to have become a convert to this method of contemplating the hypothesis of form ; for Sir William Hamilton has called attention to a note in M. Coste's edition of Locke, from which it appears that our astronomer and optician had before his dissolution learned to conceive how extended substance could be supposed producible by more than one bounded mutually repulsive solidiform piece of space.

Such are the three antithetical positions in which an atomic theory of matter has hitherto appeared in history : —1st, The general conception of material particles, as constituting material forms, in opposition to idealism ; 2d, That of indivisible, always at least actually indivisible, particles, in opposition to endlessly divisible molecules ; and 3d, That of ultimate atoms, with solid central nucleuses, in opposition to mathematical centres of repulsion. I say nothing about which antithesis is the right one for the profitable study of the subject, believing none of them to be completely so. In truth, they are all party views of the subject ; and I solicit your attention to the fact, that the method in which I last Satur-

day expanded what I regard as the legitimate view of the atomic theory, evades all the difficulties which beset these now historical methods ; and trust you will notice how the true can come out of them all, and gather round the eminently practical points to which all this is leading the way. It seems to be necessary to put this so strongly, because I understand that some of you thought me needlessly difficult in my phraseology last day, as if I were making an unnecessary display of logical fence. It was not easy to reach this point of investigation ; and though I be now as familiar with the ground as if it were my laboratory, where I can find anything in the dark, it is not yet safe to go unprotected ; and, if you approve, I shall proceed with the same wary tread. Besides, withhold your judgment till we have done, and perhaps you will acknowledge it your reward to feel how all the theories, each of which might have led to the whole truth, if the authors had been more express in their definitions, shall have conspired out of the unburied past to bring us on our way.

The atomic hypothesis of sensible form, then, as standing in no antithesis at all, but facing every way at once, is this ; that each sensible form, or part of sensible nature, is hypothetised as being made up of individually insensible particles, by no means essentially or even potentially indivisible, but indivisible by such forces as divide their aggregates, and consequently never divided in the mechanical, any more than stars are in the astronomical, operations of nature. ‘ Each form is hypothetised as made up ; ’ this language can be held by any school of philosophy, idealistic or not, for it is true to them all. ‘ By no means essentially or even potentially indivisible ; ’ this both meets the wants of the mathematicians who *will* argue from space to concrete matter like the Stoics,

and recognises the possibility and likelihood that within the atomic is another nameless world of the universe, as the atomic is within the stellar, the stellar being within we know not what world. 'But indivisible by such forces as divide their aggregates;' this provides for all that the Greek physicists and Newton desired regarding the wear and tear of particles. Then, as we found it a direct corollary from the very first illustration of this hypothesis that *an atom is neither solid, liquid, nor gaseous*, it is removed far above that vulgarity of conception which offended the subtlety of Zeno, Leibnitz, and Boscovich; while Democritus and Dalton themselves would allow that, if atoms are to be reasoned on mathematically at all, each must be defined as a point repulsive up to a given generated periphery, then attractive to a diameter polar to that of the first sphere, then repulsive and so on: just as the sun is to the astronomer a centre of ascertained comparative force. Such is the atomic hypothesis we are about to apply to the facts of nature. It is eclectic, but was not constructed by the eclectic method; which I always distrust in physics, fearing that the sedulous distillation of all the good that may be in all the doctrines may end in leaving only a many-visaged *caput mortuum* in my receiver, while the spirit shall have been shed abroad and lost. Eclecticism is golden as a product, but may be fraught with danger as a process.

It has already been mentioned that the facts hitherto observed in external nature, which have to be illustrated by the transmitted radiance of the hypothesis now under elaboration, and are to illustrate it in return by the light of reflection, are comprehensible under three heads—mechanical, chemical, and astronomical observations.

The first, or such as pertain to sensible forms, are the

most obvious, and alone engaged attention till the beginning of the present century. A solid form can be compressed in some degree, sometimes temporarily, as in the cases of caoutchouc and other elastic substances ; and sometimes permanently, as in the instances of zinc, lead, and other metals, the specific gravities of which are increased by the process of hammering on an anvil ; and still more curiously, perhaps, in those of carbon, boron, and silicon, which, prepared at temperatures below 810° , are respectively bluish black, deepest olive-green, and dark nut-brown, and so diffusible through vitriol of the density of 1.9 as to seem dissolved, but after ignition are all of them so black as to be undistinguishable from one another to the eye, and to sink at once in such sulphuric acid even in the state of fine powders. Suppose then an array of facts of this kind, then observe the effect of heat on bodies. Let the temperature of a solid, say ice, a considerable way below the freezing point of water, be exalted, and it shall expand, till on reaching 32° Fah. it shall begin to flow down in the form of water, which shall swell in its turn, till on reaching 212° , it shall commence to start into the large dimensions of steam (1700 for every one), and the limits of the dilatation of steam by successive increments of heat shall never be discovered by experiment, any more than the final bulk down to which a solid could be made to shrink by what is called the abstraction of heat ; steam, like every other gasiform body, being in fine far more compressible than the most elastic of solids. In this illustration, I have, of course, omitted notice of the apparent anomaly of ice being specifically lighter than water. From the analogy of the known, and especially from the discovery of the liquefaction of what used to be called permanent gases by Faraday, and its extension to the solidification of the

same by Thilorier, it is fairly deducible that all bodies are susceptible of these three changes ; so that this is the type of myriads of similar instances. It is unnecessary to multiply cases of an altogether similar and mechanical kind. You see how the hypothesis explains these types. Ice is an aggregate of individually insensible particles indivisible by the forces which divide ice ; in more condensed ice the centres of these particles are nearer, and in more expanded ice farther from each other ; in water they are more remote still ; and in steam at 212° they have passed *per saltum* to a very much greater distance, while elevation of the temperature of that form removes them more and more indefinitely ; and all this is irrespective of the question of how exaltation of temperature is connected with these phenomena of distation among the constituent molecules. Note here the expressness of the definition, ‘ indivisible by such forces as divide ice ;’ for other forces *can* infringe on the integrity of water particles, and bring out oxygen and hydrogen ; and this brings us to the consideration of that department of atomics which is the peculiar erection of our own times—the chemical argument.

Without inquiring too quaintly into the capital discovery of the Brothers Wenzel, published at Dresden in 1777,—that the same weight of an acid, say the nitric, as is competent to the saturation of a given weight of a base, say oxide of silver, is able to saturate quite different weights of all other bases, say soda, and all that is included in such a proposition ;—or, noticing particularly how Richter, in 1792, followed up this thought, and published tables of the chemical equivalents of several bases and acids ;—let us pass at once to the all-embracing enunciation of the doctrine of chemical equivalents in connexion with the atomic

hypothesis, as first communicated by John Dalton to the Manchester Society in 1803, then made known by him in Edinburgh to an audience precisely similar to that which is now before me, and eventually published to the world in his *NEW SYSTEM* in 1808. I should be only too glad to trace the progress of his thought among the crude details by which he found himself surrounded, and indicate how its formative influences have gradually brought a created world out of an incondite chaos, reducing every minutest particle into unison with the whole, and circumfusing all with light so searching that it reaches everywhere ; but your time forbids. Suffice it that, taking chemistry as it has been reared on the foundation of Dalton's principle by the hearty collaboration of Davy, Gay Lussac, Wollaston, Thomson, above all Berzelius, and the rest, we educe the essence of the argument, consider it, and pass on.

On the threshold, it is evident, that if neutral salts be composed of one particle of acid and one particle of base, the tabular views of Wenzel and Richter are at once intelligible. Particles of nitric acid, phosphoric acid, oxide of silver, and soda, are of different weights, and the discovery of Wenzel is a necessary consequence. Then if any of those bases unite in two or more different proportions with any of those acids, forming quite different compounds, it is an anticipatory necessary consequence that in such series of compounds the proportions of acid shall bear the simple numerical relation of 1, 2, 3, 4, to each other ; and hence an analytical test. There are two carbonates of potash ; analyses of a hundred parts of both, reduced to a common number—48 for the potash—gives 22 parts of carbonic acid for one carbonate of potash, and 44 parts of the same for the other carbonate. The anticipation is realised ; and the former

may be considered to be a compound of an atom of potassa with one of carbonic acid, while the latter is composed of an atom of potash with *two* of carbonic acid. Again, there are three oxalates of potash, and the analysis of them, reduced in the same way to a common numerator for the potash, gives

K O (potassa)	48 + \bar{O} (oxalic acid)	36 for the oxalate.
K O	48 +	72 for the binoxalate.
K O	48 +	144 for the quadroxalate.

and the speculative view is made good.

Once more : Oxygen combines with Nitrogen in five proportions—

N 14 + O 8	= nitrous oxide.
N 14 + O 16	= nitric oxide.
N 14 + O 24	= hyponitrous acid.
N 14 + O 32	= nitrous acid.
N 14 + O 40	= nitric acid.

How is this striking numerical gradation, accompanied as it is by equally interesting gradations of physical and chemical properties, to be explained? N. O. of 1 to 1, and so on. Other instances I might bring before you ; suffice it to say that there are accumulated thousands of such analyses, without a single exception having yet been found. There at first, however, appeared to be anomalous instances, *e. g.* :

Fe (iron)	28 + O 8, or 1.
Fe	28 + O 12, or $1\frac{1}{2}$ = Fe 56 + O 24, or 2 : 3.

But the latter may be considered as a compound of Fe O^2 + Fe O ; which, in turn, can combine with Fe O, and produce the black magnetic oxide of iron. This type of a multitude of seeming exceptions only comes in proof of the rule, to use a common phrase. So much for one vast assemblage of chemical observations, for the most

part discovered at the suggestion of the principle round which they crystallise with so much regularity. There is another in the dynamics of the science. The black Hg O (oxide of mercury) is composed of Hg 202 + O 8; but exposed to light, or even rubbed in a mortar, and especially at a slight elevation of temperature, it is resolved into the red oxide and metallic mercury. The hypothetical explanation is, that the equivalent of Hg is 101, that the black oxide is a feeble compound of Hg O (101 + 8) with Hg (101), and that it falls down into its constituents under the influence of the agencies mentioned. The same holds of Ag (silver) O + Ag, Pb (lead) O + Pb, and many others. The series of Mn (manganese) oxides illustrates the same thing.

Mn 27 + O 16, at a comparatively low temperature, gives off 4 O,
and leaves

Mn 27 + O 12, which, at a still higher temperature, gives off
other 4 O, and leaves

Mn 27 + O 8.

The *rationale* of which is, that of two atoms of Mn O² one gives off 1 of its oxygens, and there remains a compound of 1 of Mn O = Mn 2 + O³. Such are types of another class of facts. There is another crowd beyond them both. Almost immediately after the appearance of Dalton's work, Gay Lussac and Humboldt announced an equally exact relation between the combining volumes of bodies with that which exists between their combining weights, a special proposition which at once marshals itself under the general one which has just been illustrated. Water is composed of 100 cubic inches of oxygen and 200 cubic inches of hydrogen; and the deutoxide of hydrogen of 200 cubic inches of oxygen and 200 cubic inches of hydrogen; ammonia,

of 100 cubic inches of nitrogen and 300 of hydrogen ; carbonic oxide, of 100 cubic inches of carbon vapour and 50 of oxygen ; carbonic acid, of $100\text{ C} + 100\text{ O}$. Again, when two gases combine, their product is generally less than their sum. Now, two volumes of carbonic oxide with one volume of oxygen form one volume of carbonic acid, the diminution being a submultiple of the sum, one-third ; three volumes of hydrogen and one of nitrogen = two volumes of ammonia; and so on. The conclusion from all this is manifest in connexion with the atomic hypothesis. If each water particle be composed of one oxygen and one hydrogen, then a hydrogen is twice as large *when free* at the same temperature as an oxygen. I say *when free*, for these words have a meaning which has hitherto escaped reflection, unless indeed this be what the sagacious and ingenious Prout would be at in his *Gulstonian Lecture*. If each water particle be a compound of $1\text{ O} + 2\text{ H}$, then an H is of the same size as an O ; but whatever be the real relation between these equivalent combining volumes, and those equivalent combining weights of bodies, the manner in which they both illustrate the atomic hypothesis needs no further comment of mine even for the use of such as now study it for the first time.

Such is Dalton's great discovery of the theory of definite proportions and chemical equivalents. Only a general view of it has been now presented, because in this part of the course of thought we are pursuing we have to deal solely with the ascertained facts which are explicable by the molecular hypothesis, and not the uncertain principles which have been grafted by Dalton and his followers upon these facts taken in connexion with this hypothesis. Accordingly the canons for determining the *true* comparative weights and sizes of the molecules of different sensible forms which have been

laid down by the discoverer himself, Prout, Berzelius, and Mitscherlich, as well as Davy's sulphat-oxygen hypothesis of saline constitution, Liebig's hypothesis of compound radicals, and the common doctrine of affinity since the antiphlogiston movement of Lavoisier down to the present hour, are left for discussion in their turn. This is the place, however, to observe how chemistry, as a special part of atomics, modifies the general hypothesis for its own purposes. For the chemist, each compound particle, itself individually insensible, is proximately made up of less compound atoms indivisible by the forces which divide their product. Not that by his analyses any compound particle has ever yet been broken up into such chemically indivisible atoms, for no one is sure that all the elements are chemically simple, and I believe that they are not. Compound particles are separable by chemical reagents into more or fewer simpler ones (sulphate of iron proximately into sulphuric acid and oxide of iron, and then into sulphur, iron, and oxygen, for instance), just as any crystal can be broken into larger or smaller pieces by mechanical forces; or just as it is conceivable that this earth might be splintered into 2 or 100 planets by some imaginable astronomical analysis, of which I by no means intend to hint the probable realisation. I make the conjecture only to illustrate the principal idea of these Lectures down to this point; the idea that, even if we reach a chemically ultimate atom, and discover that in all terrestrial forms there is only kind of such chemical ultimate, one element, we shall not have done with inexhaustible nature; inasmuch as, under the sky of that atom, proceed worlds of material existence as different from atoms as atoms from compound particles, as compound particles from crystal shapes, as shapes from stars or planets, as stars and planets from solar sys-

tems, as solar systems from firmaments, or as firmaments from whatsoever other fane the Dweller in temples not made with hands has built for Himself. This is not said merely to oppress with such emotion, too deep for joy, as arises from the sense of the utter indefinitude of creation as well below and within as above and around us: save for its practical connexion with the mathematical definition of an atom for the purposes of experimental discovery, it should have had no place here. By Newton, an atom was defined to be *a solid central nucleus surrounded by spheres of force*; by Boscovich, *a central or focal point with spheres of force*; but for the atomician who will investigate the properties of an actual chemical particle, it is neither: of which afterwards.

It is time to glance at the astronomical facts which appear to be intelligible when examined under reference to our hypothesis; but only glance, for on them and their dependencies I have no critical strictures to offer. They consist of certain demonstrations by Dr. Wollaston, that minutest of lynx-eyed observers, and most widely learned of our country's chemists, which are to be found at large in the *Physical Transactions* of the Royal Society of London. Dr. Wollaston argues, that if matter be infinitely divisible, the atmosphere of the earth must be unlimited in extent, seeing gases expand and expand in proportion as compression is relieved. Being unlimited in extent, and diffused through the inter-astral spaces, that atmosphere would not be in equilibrium unless the sun and other heavenly bodies have gradually densified atmospheres of it gathered around them, proportional to their quantities of solid and liquid matter. Now, such an arrangement would, in accordance with the laws of optics, be productive of very sensible refraction of light coming to our

earth from any luminous body in the neighbourhood of the larger of them,—say the sun; but Kater and himself found the calculated and the observed positions of Venus, in her transit during May 1820, to be the same. There is, therefore, no thicker atmosphere of the same texture as ours condensed about the sun proportional to his matter; . . . our atmosphere is not shed throughout the system, but is limited in extent, . . . and matter, as we know it, is not infinitely divisible; whereas, if matter be proximately composed of homœomeric parts or particles, the limited reach of the atmosphere is as explicable as any other fact in physics, inasmuch as it shall cease to swell beyond the surface of the earth just at that periphery at which the diminishing mutual repulsion of its constituent particles shall be balanced by the force of gravitation. On this principle, it has been computed from data furnished by the chemist regarding the ingredients of the air,—their proportions and their specific gravities at the level of the sea,—that the atmosphere is about forty-five miles high.

He leads out another proof of an entirely similar kind regarding the invisibility of Jupiter's fourth satellite, when in a position in which, according to the supposition of the unlimited scope of the terrestrial atmosphere, it ought to be visible, in agreement with the same law of the refraction of radiance passing through a medium of varying density. This is more elaborate, and accompanied with numerical calculations regarding the size and distance of the great planet under consideration. On the principle involved in these, Dalton has published a Theory of the Constitution of the Atmosphere, and Faraday a series of experiments on the Limit of Vaporisation, from which he rises to the same conclusion as that to which Wollaston descends. I do not refer to the views derived from

certain of the phenomena of twilight by Sir John Leslie, who computes the height of the atmosphere to be 1638 miles, as they do not seem to be pertinent to this aspect of the question.

In order to return at once to our proper work of criticism, let a single instance more of this kind be adduced and dismissed, but more as a fanciful illustration for the purpose of taking breath than as a demonstration, because I confess it is reared on a mere conjecture. In conformity with the law of gaseous diffusion, first promulgated by Dalton in 1808, then opposed by several of the most eminent writers on such subjects at that time, and eventually corroborated by Professor Graham in 1826, it obtains that two masses of different kinds of gasiform matter, placed in contact, whether side by side or one above another, do not remain in apposition, but silently inter-diffuse their volumes till they be mutually dissolved, and they have become a homogeneous volume. If a phial were filled with carbonic acid, and placed in the laboratory below stairs, another with hydrogen and put on this table, and they were allowed to communicate by means of a tube of the very smallest bore, the hydrogen would, in spite of its levity, immediately begin to ooze slowly downwards, and the heavier carbonic acid to soak as surely up, file of particles crossing file of particles, without entering into chemical union, till by and bye both vessels should be full of an equal mixture of the gases. Now, it has been guessed that Encke's is an ærial comet, like a soap-bubble without its iridescent film of moisture, other celestial bodies being seen through its substance. Be it so an instant; only an instant, however, can it be so if matter be infinitely divisible; for, if our atmosphere be of unbounded extent, it must swathe this thin comet, as well as the rest of the unwearied travellers, through the

ethereal. But two gases cannot remain in contact, and the ill-constructed fairy should melt away, and be drawn in gauzy folds around the sun and planets, instead of gaily flying through the sky on wings of finer than the finest gossamer.

I have now surveyed the three tribes of facts to be rendered coherent and luminous by the molecular hypothesis, which was last day first rightly defined and illustrated, then approved to be a legitimate use of the philosophical postulate on the plea of a radical analogy between astronomy and chemistry, the objects of the former of which are *known* to possess an analogous constitution to that which is subsumed for the objects of the latter. The fourth part of the work which I have undertaken, viz., the erection of a permanent definition of chemistry for the application of the mathetic method of the mixed sciences, cannot, however, be proceeded with until certain debatable questions in the present theory of the science be discussed. And first, for the canons by which chemists have endeavoured to fix the relation between the real atomic weights of different kinds of molecules and the ascertained combining equivalents, both by weight and volume, of the sensible forms composed of such particles. Here it is better to be specific at once.

Nine parts of water contain 8 of oxygen + 1 of hydrogen, and Thenard's oxide of hydrogen 16 of O + 1 of H ; but, though either 8 or 16 is doubtless the combining equivalent of O (and it is better to state it as 8, seeing water is the only one of the two compounds which exists in nature), there is nothing in the facts themselves to decide whether a water particle be composed of 1 of O and 1 of H (with the direct inference that Thenard's

oxide contains $2\text{ O} + 1\text{ H}$), or whether a water particle be the product of $1\text{ O} + 2\text{ H}$, with the equally direct inference that Thenard's oxide is produced by the combination of $1\text{ O} + 1\text{ H}$. In no case can mere analysis discover this kind of secret. Dalton, perceiving this, proceeded straight to the construction of presumptive rules for the solution of such problems, founded on arbitrary and extrinsic considerations, which have been modified sometimes one way, sometimes another, nay, often for one instance one way, and for another another way, by following but by no means unanimous chemists. Accordingly, while all are agreed about the combining equivalents of bodies, there are many differences regarding their atomic weights; for example, for Gay Lussac the atomic weight of oxygen is 16, and for almost every one else it is 8; with Dalton, nitrogen = 28, and with others 14; while Berzelius, retaining the latter number, represents it as combining in double-atom; one regards mercury as 202 times heavier than hydrogen, another 101, and so on. All this surely at least suggests the possibility that the so-called canons have not reached the recesses of the subject.

Dalton's first principle was, that when there is only one compound of two substances in nature, and no other can be produced by experiment, which is so potent in the formation of the most grotesque and unstable unions (such as the fulminating acids, which have only to be touched to unchain and explode their constituent gases), that compound is to be regarded as composed of one atom of each of its ingredients, and the conclusion started from as a salient point. Now, there is and can be formed only one product of nitrogen and hydrogen, ammonia; a stable body which performs a most important function in the economy of vegetation, according to

the recent discovery of Liebig ; but it contains 14 of N and 3 H, so that H being taken for *unity*, according to this rule the atomic weight of N must be 42. Then applying 42 for N to the series of its unions with oxygen,* the N O, if O be taken as 8, according to Dalton's second canon, must be composed of N + 3 O, and nitric acid of N + 15 O ; and the ratio in the series for O, 3, 6, 9, 12, 15, instead of 1, 2, 3, 4, 5, a conclusion which no one has ever entertained. But it is not enough to reject ; let us find a reason, and not condemn the first thought of a man like Dalton for nothing. Now, in Dalton's reply to a review by Bostock, I find the clearest sentence that ever was written on the combination of atoms, which not only illustrates the constitution of ammonia as N + 3 H, but furnishes a clue which, with other help, may conduct us to the very thing he sought with so much avidity, viz., a permanent canon. 'If any one should inquire, for instance, why one part of carbon which takes 1·28 oxygen, or 2·56, does not also occasionally take 3·84 and 5·12 parts of oxygen, it will be understood that the reason I should assign is, that in the state of C O² there are two atoms of oxygen combined with one of carbon, and a third or fourth atom of oxygen, however it may be attracted by the carbon, cannot join it, without repelling one or more of the atoms of oxygen already combined. The attraction of the carbon is able to restrain the mutual repulsion of two atoms of oxygen, but not of three or more.' This lucid conception may be made more lucid still, perhaps, by the counter statement in astronomy, that a sun cannot be overloaded with planets. Suppose that by some intensification of its forces, or relaxation of those of the planets, it could be what for its and their natural state

* See page 38.

would be *overloaded*, then the instant this relaxation or that intensification should be rechanged to the normal condition of the forces, *the temporarily larger solar system would* fling off the supernumerary planets and become as it was before the unnatural combinations. Apply this to ammonia. In a compound of two gases, nitrogen and hydrogen (no matter for the number of atoms at present), there are two forces tending to its disruption, the mutual repulsion of the nitrogens in contiguous particles, and the mutual repulsion of the hydrogens, the decomposition (as if ammonia were decomposed by passage through a tube at some high temperature) being the resolution of those two, or rather four forces. Nitrogen is 14 times denser than hydrogen, and the atomic weight is as 14 to 1; and when they unite, not only must the ingredient nitrogen be 'able to restrain the natural repulsion' of the hydrogen or hydrogens which may combine with it, but the nitrogen itself must be covered from the repulsion of the nitrogen in contiguous particles; so that, considering the gravities and the comparative atomic weights of the two gases, it is exceedingly likely that the stablest combination shall be one in which a nitrogen shall have taken on more than one of hydrogen. It remains to be seen whether there be data of a purely dynamical sort to determine *how many* planetary hydrogens there must be in a compound atomic system of ammonia. If there be, or if any can be found, then the atomic theory shall be perfect; but whatever principle shall be in the heart of such data, when they shall have been found, must summarily have dismissed those superficial presumptive evidences which have hitherto distracted chemists, and made them differ from one another. It shall not contest any one of the present views, but

supersede them all in virtue of the greater elevation of the point whence it shall be taken. Otherwise there is no hope. At all events, Dalton's conception, drawn from Nature, contradicts his arbitrary rule regarding the strength of twosome combinations, while it illustrates the fontal idea of all his labours.

LECTURE III.

I CONCLUDED my last Lecture with a criticism of Dalton's first canon for the determination of the relation between the chemical equivalents of sensible forms and the weights of the particles of which such forms are composed ; and found that, while it is not in conformity with any ascertained principle of physics, it stands in direct contradiction to one which was precisely indicated by himself, in his explanation of the fact that carbonic acid cannot take on another particle of oxygen and pass into the supposable state of teroxide of carbon. The rest of his rules all rise out of that which has been discussed ; and it has been customary for his followers to modify them in their application to special instances, by considerations, drawn sometimes from proper chemical analogies, sometimes from the study of the crystalline forms different bodies assume in the light of Mitscherlich's principle of isomorphism, and sometimes from comparison of specific gravities, but never upon any fixed principle deduced from Nature elsewhere, and otherwise known. In methodical pursuance of our aim, this were the place to examine, with a critical eye, these fluctuating and motley modifications of the original canon of our common master ; but it has been suggested to me that it is impossible to make such strictures as

are necessary intelligible to any other than an unmingled audience of chemists ; inasmuch as, though the reasonings that should be led out must, from their highly general nature, be very simple, each illustrative fact cannot be brought under the eye of any but the accomplished student of the science by the mere pronounciation of a name, especially in its suggestive character as the type of a multitude of instances analogous either by contrast or resemblance. The same kind of things is to be said of the admirable Davy's hypothesis of sulphat-oxygen, as elaborated by the grateful Liebig into that comprehensive doctrine of compound radicals, which has already done so much for the chemistry of organic bodies ; one among many illustrations of the way in which the smallest seed which genius drops in the course of its prouder career, is sure to be some day appreciated by a kindred mind, cultivated, and allowed to become productive. In fine,—if you will grant that, while we shall thankfully receive the numbers usually affixed to the different elements as the combining equivalents of these bodies, we will not, on any condition, believe that in all cases they represent the comparative weights of the particles which compose these bodies, but rather feel the necessity of being on continual outlook for some sure principle of dynamics to fix the relation between these atomic weights which we must discover, and those combining equivalents which are already discovered,—I will proceed to offer a view of my own doctrine regarding the only vital question in chemistry to your indulgent consideration, and then conclude with a definition of the objects of the science sufficient for the purposes of the mathematician. Let it be understood, however, that the doctrine in question is by no means proposed as a positive discovery, but only as an idea susceptible of

practical investigation in the *a posteriori* method, and which, accordingly, may be eventually realised as a law of Nature by the labours of the laboratory, while, so long as it is cherished solely as an initiative thought, it can never conduct to error. You have seen how the most general conception of the homœomeric constitution of sensible forms has been solidified, like the heavenly bodies of Herschel out of their nebulous matrices, by the analyses of Wenzel, DALTON, Berzelius, and their followers; and are, doubtless, ready to grant Novalis that 'the sceptic has contributed just as little as the vulgar empiric—*i.e.* absolutely nothing—to the enlargement of the field of knowledge;' while 'the true builder of hypotheses is no other than the inventor, before whose eye the unknown dimly floats before its discovery,—who carries this faint image into every observation and every experiment, and at length, by means of bold comparison, of repeated contact and collision of his thoughts with experiment, arrives at the *idea*, which stood in a negative relation to positive experience. Both are then forever connected, and a new celestial light surrounds the power which is born into the world.' Let us endeavour to delineate the image in the present instance with as little faintness of outline as possible.

The alchemists of Europe,—beginning with Roger Bacon, who wrote the *Opus Majus* at the beginning of the thirteenth, and ending with Paracelsus, who ushered in the revolution of Le Fevre at that of the sixteenth century,—curiously and unwisely, though always with a certain profundity of method, interwove the *a priori* speculations of the Greeks on the hypothesis of matter, with the rudely observed chemical facts, and allegorically worded *a posteriori* theories, which were borne west-

wards from Arabia and the East, on those irregular currents of communication which were begun and sustained by the Crusades. The polypharmists, headed by Geber, who compiled his *Summa Perfectionis* in the eighth century, held that arsenic, mercury, and sulphur are the elements of all other chemicals (for to them chemistry was no more than an artificial science of chemicals, as it is for the vulgar to-day); that the metals are compounds of sulphur and mercury in different mixtures; and that the metals are consequently transmutable into one another. Immediately after Geber, this school became one of mere iatro-chemistry, or *chemical medicine*, in the persons of Rhazes, Avicenna, Mesue, and Averröes, who, full of faith in the power of their art, began to dream of a *panacea*, and were even fain to believe that Geber's red solution of gold was the veritable *elixir* of life. The Greeks, on the other hand, inculcated, as we have found, the idea of a *πρώτη ὕλη* or primal matter, of which the four elements (water, earth, air, and fire) are the first unfolded forms, and the types of four vast classes of secondary and derivative shapes; the word "water," for instance, being better rendered "moisture," and standing for the abstract conception of that collection of qualities which is generally called moisture, and is specifically embodied in water, just as the term *Rosaceæ* in botany generically represents all rosaceous plants, and specifically a rose or any other genus of that natural family. In truth, earth, water, and air are just our solid, liquid, and gasiform conditions of body expressed in concrete: while *fire* is the shadow of the *imponderable matter* of modern times. Such were they, at least, so long as the original conception, which they were invented to convey, was kept pure.

The alchemy of the thirteenth and following three

centuries was engendered by the providential union of these two most compatible elements; and it took three hundred years for the significance of the former so far to gain the ascendancy over the obscured, misunderstood, and now for a hundred years eclipsed meaning of the latter, as to produce that positive chemistry of Stahl, Lavoisier, and Dalton, to which not only the arts of life, but the theory of nature has become so much indebted. Events have approved this to have been a most desirable consummation; but it is time to inquire if it be not possible to restore the neglected and older element of the science, to bind it in indissoluble union with the now deservedly predominant but younger, and to associate the improvisatorial sages of Greece, the busy polypharmists of Arabia, the distracted but indomitable alchemists of Europe, the triumphant experimenters of our own chemistry, and the conservative yet unresting workmen of a future atomics, in one fraternity of productive men. It is time to institute this pregnant investigation, because analytical chemistry has ceased to advance, and continues to grow only by the superficial extension of its present domain.

The best consequence of the singular combination of the manual activity and fanciful mystery of the oriental elixir-hunters, with the yet impracticable but clear depth of the western speculators, in the indefinite form of ever struggling alchemy, was the preservation of that unity of principle which was never wholly extinguished in the darkest night of the middle ages, although it has been hidden by the half-true scepticism of later days. The general fact of the chemical combination of two different substances, and the production of a third, as its result, is the oldest *practical* truth in the science; and the philosophical alchemists

(Albertus Magnus, Arnoldus, Lullius, Basil Valentine, and their peers) on the one hand observing it exemplified in their crucibles and alembics under a thousand forms, and on the other, receiving with reverent faith the dogma that all the endless variety of forms is the varied phenomenal manifestation of one CHAOS, which must therefore be capable of unfolding and again re-folding its parts independently of external reaction, were naturally led to the conclusion that the more alike two uniting specific forms were, the stabler their union. Brimstone is of the nature of oil, and they draw to one another. The metals are akin to quicksilver, and either they lick it up, or it devours them, and so on. *Æqualitas enim, ut Pythagoræ placet, amicitiae parens est*: 'For equality, as pleases Pythagoras, is the parent of friendship,' was their favourite maxim in that commoner part of their science, which treated of ordinary combinations, as distinguished from *the* chemical and 'hermetic' work of transmutation, in which they all unite in asserting that no second body is concerned, nothing being to be added to or subtracted from a metal, when by some vaguely conceived kind of self-involution it shall be changed into a nobler. In such self-involution a metal is said by the hermetics 'to kill itself; to espouse itself, to impregnate itself, to engender itself, to be born again of itself, to make itself white, to make itself red of itself.' Says the stone to gold and mercury in the *Ancient War*, 'Aristotle says of me, we add nothing more to it, and we change nothing in it: O how admirable is this thing which contains in itself all things!' It was in reality in the department of common chemistry, however, that the best man carried on experimental researches; witness Roger Bacon, who believed but never professed the philosopher's stone, any more than Albertus Magnus, and others whom I have

named, down not only to Paracelsus, but to Stahl, who firmly believed that all the metallic calces were what may be called intra-corpuseular or isomeric modifications of one common calx. These men only *wrote* about transmutation, and wrote very sublimely too for the most part, and were instrumental in preserving alive the great old conception which had been handed down to them for the behoof of a later posterity. Meantime they laboured with great skill at the operations of common chemistry; and their opinion concerning the natures of different bodies which are susceptible of entering into chemical union with each other was, that they must be of kindred qualities. Heretics indeed, did, from time to time, insist that opposite natures are the best adapted for true chemical union; and the disputants would enforce their principle by analogies drawn from no more remote a subject than the theory of marriage; but sometimes also from the sky, where the cool moon appeared to be the 'silver bride' of the burnished and 'golden-tressed sun.' To pass by the recusants, however, this conception, of the necessary similitude of combining substances, retained its hold a considerable time after the dawn of the present era of positive discovery, which, refusing to acknowledge the claim of intuitive speculation, has erected a new scientific structure altogether, on the solid foundation of the facts of nature. Accordingly, Barchusen, who has already been mentioned as having introduced the word *affinity* into the nomenclature of the science, implied, in the etymology of the term he selected, that the conception to be expressed was that of the union of substances *less different* than alike: and indeed it was defined in such a manner as leaves no doubt that the combination of similar bodies, *the subjects of AFFINITY of nature*, was then regarded as the object of chemical inquiry. It was

Boerhaave who first restricted the term 'affinity' to the force productive of the union of dissimilar substances, and drew an analogy between the *cohesion* of the parts of the *same* substance, and the *combination* of two or more *different* substances; and it has ever since been taken for granted, that such chemical affinity is exerted solely between heterogeneous particles: a particle of oxygen can combine chemically with one of carbon or of hydrogen, but not with another part of oxygen; the same force as chemically unites an oxygen to a carbon particle, and produces a compound particle of carbonic oxide, unites two oxygen particles so as to produce just the smallest conceivable *mass* of oxygen; a definite conception, whether it be true or false. Indeed, since the conception of *affinity* was originally generalised from observations made only on the combinations and new productions of unlike particles, this assumption was not very avoidable, although by no means necessary or sufficient, as we shall see in a little; and from such a conclusion it was easy and natural to pass on to the inference that the force which binds dissimilar particles in the substance of one compound particle, is identical with that by which homogeneous particles are linked each to each in the production of a sensible form. Hence, this unfounded proposition has held its place through all the succeeding history of the science, as the first principle of its dynamics. Not to rise any higher than the Lavoisierian era, the eloquent and precise Fourcroy, in every respect the fittest representative of the school of his illustrious countryman for our present purpose, substitutes affinity for molecular attraction, and classifies it into two species,—the affinity of aggregation, and the affinity of composition. He then lays it down as the *first law* of the affinity of composition—'*That it has place only between*

bodies of different natures, or between dissimilar particles. Berthollet even refines on this about the two affinities, and hints that the specific appellations are unnecessary, inasmuch as the species are changeable into each other. Such a definition has been repeated, either expressly or by implication, with nothing but superficial variations of phraseology, by Dalton, Davy, Berzelius, Mitscherlich, Dumas, Graham, and every systematic writer of note with whose works I am acquainted. Professor Graham has, like Berthollet, refined with some subtlety on the common notion, and offered a hypothesis that the particles of the metallic elements of an active voltaic circle assume the binary arrangement, forming *pro tempore* molecules the prototypes of haloid bodies, in which both the salt-radical and the basyle elements have their representatives; an arrangement which he supposes to fall down the instant the circle is broken. Yet in his text-book, in which this conjecture is published, it is taught that 'a specific attraction between different kinds of matter must be admitted as the cause of combination, and this attraction may be conveniently distinguished as *chemical affinity*.' This able author is specified only as the latest and best of his time.

The manner in which a particle should be represented diagrammatically, in agreement, in the first place, with the hypothesis of form, as laid down in my former lectures, and in the second place, with this modern definition of affinity, is this,—a molecular centre (neither a point nor a solid nucleus) surrounded by three spheres of force; the first repulsive, and never overpassed in the molecular operations of nature, else fixity and death were the order of molecular nature, instead of motion and

life ; the second attractive, the third repulsive. Two particles moving (or rather standing, for the conception of atomic revolutions has not yet been generalised) in relation to each other at the distance of the third sphere, constitute the smallest possible mass of the vapour of sulphur ; while the same two particles of brimstone at the distance of the first sphere (also one of repulsion), produce the smallest mass of solid sulphur ; whereas a particle of brimstone at the distance of its own third sphere from a particle of hydrogen, forms the smallest mass of hydrogen *diffused*, in accordance with Dalton's law, through the vapour of sulphur (supposing them diffused in the ratio of particle to particle), while a particle of brimstone united with one of hydrogen at the distance of its first sphere, produces a compound particle of the new sensible form called hydrosulphuric acid. Now, before finding that such a definition is insufficient for even the present wants of science, it is necessary to consider another element which enters into this kind of question, that of the distances at which particles, I will not say revolve round, but stand related to each other in both sensible forms and compound particles.

It has always been recognised as an essential principle that particles are not, even in the most adamantine of solid bodies, in actual contact, except, of course, by such as have found refuge in such hypothesis as that of Zeno, Leibnitz, and Boscovich, and had consequently no need of a principle of this kind. If the particles of bodies were once in actual contact, there would not only be an end to their compression by external force, as well as their contraction by reduction of temperature ; but it is inconceivable that they should ever be separated again by secondary causes, and, if permission were given

for such a consummation, our 'unresting yet unhasting' creation, with its innumerable spheres wheeling within innumerable spheres, would instantaneously collapse into a corpse reduced to petrification. Nay, a 'crystal stone,' with the myriad interweaving evolutions of its animated particles, is no fit image for such a death ; but, if you will let me correct the figure, and yet continue that metaphorical language by which alone the thought can be even dimly expressed, it were all one as if nature were the melodious word of the Creator congealed into a peerless, but all unmusical statue, instead of a breathing form of beauty, whom dutiful children are fain to impersonate and love as their mighty and graceful mother. But, leaving that atmosphere of wonder with its alternative, in which all science begins as well as ends, I find that notwithstanding the universal belief that the particles of bodies are never in actual contact, a most unfortunate misconception regarding their distances from one another has hitherto prevailed, in the form of one of those *idola specus*, which so frequently infest the childhood of science. Particles are insensible ; so are their distances from each other. But for all that is contained in these premises, these distances may be as great in proportion to the diameters of those particles, as, say the distances of the planets from the sun, in proportion to their diameters and his. There is nothing against such a conception beforehand ; our analogy is high and powerful in its favour ; and analogy is the only possible initiative guide to the unknown. At all events, Nature, in the simple fact of the insensible character of atoms and atomic distances, says nothing determinate either way. Yet, observe how partial reflection, or rather the most impartial absence of thought, has decided and dismissed the question ;

for it has always been dogmatised as a thing needing no further inquiry, that the particles of bodies are *indefinitely near each other*, so that no calculations regarding their forces can be made, inasmuch as they are so very near each other, that their shapes interfere with the regular and else calculable action and reaction of their forces. It is unnecessary to speak of the poor guess of the younger Lemeray, the incompetent son of a most sagacious father, that particles are hollow cones of different sizes, which produce compound particles by fitting into each other ; nor of that crude conjecture, on the most perfect form of which the Abbé Haüy constructed his famous system of mineralogy, overturned only not many years ago by Mitscherlich's interesting discovery of isomorphism—the conjecture that different particles are different polygonal solid shapes, which, in chemically compound particles, and in sensible forms, are packed one upon another like so many bricks, the repulsive force, preventing their complete contact, being like so much mortar, well mixed with chopped hair, to hinder them from falling too far asunder.

Coming at once to Bergman,—the sagacious author of an essay on the search of truth, worthy of less timidity of spirit, and the generous discoverer of his more celebrated countryman, Scheele,—it is interesting to find that he conceived the project of applying the astronomical method of Kepler and Newton to the solution of chemical theorems, but recoiled at once from the attempt, because the particles of matter are so indefinitely near each other, that *shape* interferes with regulated force. Buffon suggests the same undertaking, but immediately withdraws his hint, because the particles of matter are so indefinitely near each other as to complicate the phenomena of force and form. It may not be right to

draw any direct inference from the circumstance, but DALTON, in his diagrams, always represents atoms chemically united as touching each other; and Berzelius, giving his opinion that the particles of metals are not essentially simple, or rather are not units, states in so many words, that in order to a particle's possession of length, breadth, and thickness, it must be made up of at least four ultimately simple atoms,—as if the earth and moon were not a spheroidal unit with an infinite number of diameters, in relation to the sun, round which they revolve in astronomical combination. In fine, this mistake as to the distances of particles, compared with the *sensible* distances of mechanical forms, and the *transcending* distances of stars, compared with their own sizes, implicitly pervades every book I have read; although it is not to be supposed that it can have yet impeded the progress of discovery, else it would have been detected and exposed in good time.

Now before it is possible to treat of atomic distances, it is necessary to fix an atomic standard of comparison, by the assumption of some unit, precisely as in the case of atomic weights; but, although such a task does not appear to be very difficult,—inasmuch as, a hydrogen diameter being taken for unity, as well as its atomic weight, distances may be elicited from atomic weights, and specific gravities reckoned from the atomic weight and the specific gravity of hydrogen as a unit,—I shall not enter on the subject, because it would lead us into such a labyrinth of technical details as it would be irksome to the majority of my audience to thread. Here I must content myself with referring the curious to the printed page, where alone such questions can be studied with advantage. It is sufficient for the present that it be shown that in all cases the

particles of a sensible form, and of a compound molecule, are a vast number of times their own diameters separate from each other.

Suppose that there be a cubic inch of ice at 32° of the same density as water, and that the particles in that cubic inch be in actual contact. That cubic inch, at 212° , occupies the space of 1700 cubic inches, in the shape of steam, so that the water-particles are in steam 425 times their own diameter more remote from each other than in the form of ice ; elevation of the temperature to 212° has removed them 425 times their own diameter from one another—*i.e.* the diameter of the third sphere of repulsion (and, by polarity, of the second sphere of attraction) is 425 times a water-particle's diameter greater at 212° than at 32° . But ice-particles are not in contact ; only their first spheres of repulsion are in contact, and those first spheres are, by polarity, equal in diameter to the second and third ; so that all the spheres are 425 times their own diameters greater at 212° than at 32° . This is true, however, only if the hydrogen and oxygen particles in each water-particle be not distated by the same elevation of temperature, it may be urged ; but it is not so, for each water-particle is to its neighbours on all sides a true unit, with its centre neither in the oxygen particle nor in the hydrogen, but in the shifting focal point of the forces of both ; and no sooner shall intensification of the forces of the constituents of water-particles by heat take effect, than the water shall be decomposed, the repulsive oxygens and the hydrogens of two contiguous particles detruding each other respectively, according to the law which was given at the close of last lecture. It is thus that the commonest phenomena illustrate the general conception of the vast comparative distances of atoms, even on the prevalent hypothesis of

three spheres of force, which, with the help of the general conception, we are now in a condition to examine, inasmuch as we must carry along with us the undeniable inference that two equal and similar particles (as two of oxygen), on whatever sphere of each other they be thrown, revolve around each other in the line of the resolution of the centripetal and centrifugal forces, while of two unequal and dissimilar particles (as an oxygen and a hydrogen) the less particle of force shall be planetary, and the other solar. Let us, however, investigate the old hypothesis not by weighing presumptive arguments, which only vex the mind and tear the question, but by rising at once to a higher ground; lay down not a counter-proposition but a superseding doctrine; and then establish that doctrine in the only way in which the loftiest physical truths can ever be made good, by seeing what it is able to explain and what to discover.*

A particle is a molecular nucleus surrounded by five polar spheres of force; the first, that of repulsion, which is never overpassed in the chemical, any more than the first repulsive sphere of the sun is in the astronomical operations of nature; the second that of proper chemical affinity; the third that of repulsion which hinders the compression of a solid body by surrounding forces; the fourth the attractive sphere of solidiformity; and the fifth the repulsive sphere of gasiformity. It is called a

* It may be noticed here, that Kant's conception of the interpenetration in the instance of chemical combination is not formally discussed, because the whole tenor of our critical studies these three days has been to show that such a conception is as inapplicable to chemical as to astronomical combination. As a methodological fiction, indeed, it is suitable to both astronomical and chemical investigations; and in the latter, on account of their complexity, I shall always use and recommend it. This, however, only in passing, for such as care for it.

molecular nucleus to distinguish from both the point of infinite repulsion, defined by Boscovich, and the solid nucleus of Newton, and to indicate that the chemist has no more to do with what is within his ultimate atoms than the astronomer with what is within his stars. Nor is it meant that there are no more than five spheres of force ; but only that the chemical atomician, contemplating matter under the conditions of gasiformity, liquidity, solidity, and chemical combination, has to consider these five alone. A particle of hydrogen, revolving like a planet round oxygen on their outermost spheres of repulsion, produces the smallest mass of these gases diffused by Dalton's law in the ratio of particle to particle ; revolving round oxygen on the second outermost spheres of repulsion, they should produce the smallest mass of an analogous solidiform substance, which, however, cannot exist, inasmuch as if the mutual repulsion of oxygen to oxygen and hydrogen to hydrogen in contiguous molecules could be so far constrained as to admit of such composition, there were no opponent force to hinder their compression into the more intimate union of chemical combination. And, lastly, a particle of hydrogen revolving round an oxygen on their third outermost (*i.e.* innermost) spheres of repulsion, produces a particle of the compound water. Two particles of oxygen revolving round each other on their outermost spheres of repulsion is the smallest mass of gaseous oxygen ; revolving on the second outermost sphere of repulsion, the smallest mass of solid oxygen ; and revolving on the third outermost (*i.e.* the innermost) spheres of repulsion, they would be chemically combined, and the two particles of oxygen transmuted by such combination into one compound particle of some other element, say sulphur for the present. The former

illustration shows that all the common phenomena of the combination of heterogeneous particles is, to say the least, equally intelligible by the old and the new hypothesis. The latter does more, for it furnishes the cue to the explanation of a class of facts, discovered only in the latest times, for which the old hypothesis makes no provision—the facts of isomerism among compound bodies. One illustration is as good as many. Cyanogen is composed of nitrogen 1 + carbon 2; but a certain compound of cyanogen, cyanide of mercury, can be decomposed by a particular method (discovered accidentally by Gay Lussac and misunderstood) into mercury, and not gasiform cyanogen, but a solid substance, paracyanogen. Paracyanogen contains carbon and nitrogen in the same proportion as cyanogen, 2 to 1. What is the difference between them? The new hypothesis of five spheres renders their relation at once intelligible. Paracyanogen is a compound of cyanogen with itself,—two particles of cyanogen revolving round each other on their innermost spheres of repulsion produce the new compound of homogeneous particles, paracyanogen, which must, consequently, contain C and N in the same proportions as cyanogen. But an *a posteriori* test is at hand. For reflect, when the temperature of a compound of two heterogeneous particles is elevated, as carbonate of lime in the kiln, the mutually repulsive forces of the particles of carbonic acid gas, in two contiguous particles of the limestone, are intensified till, at a certain point of elevation, each detrudes each from the two lime particles with which they are respectively combined, carbonic acid is set free, and quick-lime remains. This rule is of universal application to compound particles made up of two heterogeneous simpler particles; for as certainly as one of the two in each case is neces-

sarily more volatile than the other (else were they not heterogeneous at all), shall a sufficient elevation of temperature decompose such compounds of unequal and dissimilar particles. And the very same kind of observation is to be made regarding the action of reagents and electrolysis, as every well-versed chemist must perceive. In the supposed instance, however, of the chemical union of two homogeneous particles, say two cyanogens united so as to produce paracyanogen, no such forces *can* dissolve the combination; no elevation of temperature acting by the mutual detrusion, in two contiguous particles, of the more volatile, for neither constituent is more volatile; no depression of temperature, for neither is more susceptible of congelation; no elective affinity, whether ordinary or electrolytic, for neither cyanogen is the more eligible; in a word, if paracyanogen be a chemical compound of two cyanogen particles, it shall be impossible to extract cyanogen from it.*

Then this definition of the five spheres is big with

* Had Dr. Brown himself prepared these Lectures for the press, we believe this expression would have been modified into 'it shall be impossible to resolve it into two cyanogens.' There is no doubt that, by the application of a certain temperature, cyanogen can be extricated from paracyanogen, even when absolutely free from the absorbed gas, which it retains with great pertinacity; but there seems as little doubt that it cannot be decomposed into its two constituent atoms of cyanogen. As given off from it, that gas is invariably found mixed with uncombined nitrogen, with carbonic oxide or acid, if there has been access of air during the decomposition, and with traces of ammonia if the paracyanogen employed have been exposed in any way to moisture, which, also, it retains very obstinately. This, however, is easily explicable in full consistency with Dr. Brown's hypothesis of its constitution. That hypothesis only excludes the possibility of the separation of its two cyanogen atoms *as such* from each other; it does not exclude that of the decomposition of one of these into its constituents; and the instant such decomposition commences, the other cyanogen is conceivably free to come off without decomposition.

suggestions for new discovery. If this theory of isomerism be the truth of nature, then the fifty-five elements which no invented torture has been able to unfold, may be isomerically compound, and, by necessity, indissoluble by the kind of forces by which experimenters of every age have hitherto striven to wrench their constituents asunder. If a particle of boron be a compound of two carbon atoms, it shall be impossible to decompose it, and extract carbon out of boron ; if silicon consist of two borons chemically combined, it shall be vain to attempt the extrication of either boron or carbon from silicon ; and so on with the metals and other elements. Another kind of analytical force must be sought and found before such combinations can be solved ; *or* synthesis must be had recourse to in order to realise the hypothesis ; two carbons must be made to unite chemically so as to produce one boron ; two borons to produce one silicon ; or four carbons to produce one silicon ; just as two cyanogens are forced to combine in the production of paracyanogen.* It

* The following extract from Dr. Brown's *Note-Book*, of date 1847, may perhaps place the whole conception in a more condensed and vivid form before the reader :—

I. Of the idea of true isomerism.

a. Of the definition of the atom.

1. The Newtonian conception and definition of an atom is incongruous in and with itself, and therefore false. 'A solid central nucleus' of that which has no sensible form (*i.e.* is not solid, liquid, nor gaseous), by the very constitution of the figure, so to speak, is a contradiction in terms, and the error need only be stated to be refuted.

2. The Boscovichian one certainly both explains (*i.e.* renders conceivable) the phenomena for which it was constructed, and it is complete within itself ; but if the theory of isomerism to be succinctly put down here be the truth of nature, it is inapplicable to oxygen, hydrogen, and all other such atoms as the chemist employs in his reactions. Thus it is extruded from the domain of chemistry altogether, and it hereafter belongs to the unexplored but truly grand abyss of transcendental physics. It is worth remarking that an accident of the essential conception of Boscovich,

is evident that, if any one element be transmutable into another by this species of self-involution, it is easy to construct a hypothesis which should represent any number of quasi-elements (not to limit it to fifty-five) proceeding from the successive involutions of only one kind of par-

viz., that the force at the centre of the innermost sphere (repulsion) is necessarily infinite, might be called in question.

3. An actual atom (from hydrogen to gold inclusive, and all the more the atoms of all compound forms of matter) is an extended substance, not solid, liquid, nor gaseous; surrounded by successive and polar spheres of repulsion and attraction, repulsion being the innermost, and also the outermost, so far as man's experience extends.

b. Of the postulate which involves the possibility of alchemical transmutation.

Definition. That for the chemist each atom (whether simpler or more compound, but considered as a unit or *tertium quid*) is surrounded by five spheres of force, κ , a , κ' , a' , κ'' ; that κ is never overpassed in the procedure of nature; that a is the sphere of chemical combination; that κ' is that which hinders the compression of a solid body beyond a certain point; that a' is that of cohesion; and that κ'' is the sphere of gasformative repulsion, liquiformity lying in the mesoteric line of the two last.

Corollary. That equal and similar atoms, say two oxygens, may enter into chemical combination with one another, producing a *tertium quid* as different from oxygen as water is different from oxygen and hydrogen.

Lemma 1. The chemical union of two equal and similar atoms, indecomposable by any known force, shall be itself indecomposable by any known force; two oxygens, chemically united, shall be indecomposable by any known force, for neither of the two is more volatile, more fusible, more attractive or repulsive of the particles of any reagent, electro-positive to the other; in a word, o , o is as much an element as o , which may as well be representable as x , x ; in one word more, o is thus transmutable, and so are the metals and other elements.

2. All that is negative in the Lavoisierian chemistry is swept away by this postulate, nothing that is positive.

3. In particular, cohesion between equal and similar atoms is *not* the same as combination between heterogeneous ones.

4. No *mechanical* force shall be able to drive two equal and similar atoms through each other's κ' into each other's a , so as to produce a transmutation; and the inversion of the reasons why x , x once bound cannot be decomposed again into $x : x$, shows that x cannot spontaneously enter into combination with x .

ticles ; and thus, once for all, the conception which was finally lost at the birth of the sceptical chemistry of modern times, is not only restored, but adapted to the latest results of the science. As a conception only, indeed, for it remains to be seen whether or not the idea is realisable as a law of nature :—*finally lost*, for the Arabian chemistry brought with it the germ that was eventually to prevail so long over the proper *alchemical* element, which we have found to have been sent down from Greece. Albertus Magnus, of whom mention has already been made more than once, managed to adopt the Arabian hypothesis of the metals, and yet retain his belief in the possibility of a substance uniting with itself, or as it used to be dimly expressed, ‘gendering with itself, after the manner of hermaphrodites.’ The *alchemical* idea then predominated till Paracelsus paved the way for Le Fevre, by his lust for mere personal glory driving him to throw both Arabians and Aristotelians into contempt ; although he, meanwhile, held by the ancient idea himself. He says in one part, “ All composed things are of a frail and perishing nature, and had at first but one only principle. In this all things under the cope of heaven were enclosed and lay hid ; which is thus to be understood, that all things proceeded out of one matter, and not every particular thing out of its own private matter by itself. This common matter of all things is the ‘*Great Mystery*,’ which no certain essence and prefigured or formed idea could comprehend, nor could it comply with any property, it being altogether void of colour and elementary nature. The scope of this ‘*Great Mystery*’ is as large as the firmament. And this ‘*Great Mystery*’ was the mother of all the elements, and the grandmother of all the stars, trees, and carnal creatures.” It was the domination of

the analytical idea that so corrupted the Aristotelian doctrine of the four quasi-elementary and typical forms, as to suggest to the mind of Le Fevre that a more inquisitive analysis of wood might overthrow the scholastics, whom he detested, because he did not understand them. After Le Fevre's revolution, which was particularly described in my first Lecture, it became and has continued till now to be the deepest, though a latent, principle of the science, that *there must be at least two elements of things*. Hence Van Helmont—who was, in his youth, an alchemist of the first water, though of a degenerate school, but became, under the prevailing influence of his time, a very practical chemist when he grew older—abandoned his mean conjecture that water is the mother of things, and found credibility in the dogma of Beccher, who taught that God brought water and three varieties of earth out of chaos, and then left creation to the action of secondary causes. Van Helmont's supposition was mean, because it was founded *a posteriori* on the sorry observation that water, boiled for some time in an earthen vessel, seemed to be converted into earth, which fell to the bottom as a sediment. Lavoisier, balance in hand, found it necessary long after to show that this precious sediment was worn off the inside of the apparatus. Stahl engrafted his phlogiston hypothesis on Beccher's principle of water and earth, although his strong sense bound him over to the elaboration of his own practical doctrine. Lavoisier thought it extremely likely that the list of elements would be very much reduced by the advancement of analysis. Davy, the most triumphant experimenter that ever lived, constructed a hypothesis for the purpose of investigation, to the effect that the elements are compounds of hydrogen and an unknown base in different proportions, and

even determined the proportions of these in the different elements conjecturally, as well as performed many experiments in the attempt to realise his bold guess. At first he seemed to succeed; sulphur, selenium, carbon, all yielded large quantities of hydrogen to the solicitation of his trials; but no 'unknown base.' It was absorbed hydrogen that was given out. He detected his own error, and did not proceed. The gratuitous implicit assumption of the analytical chemistry paralysed the arm of even Davy, when he essayed this five-and-fifty-folded knot. The ingenious Dr. Prout, spell-bound under the same influence, supposed at one time that oxygen and hydrogen are the true elements, and proceeded to make the atomic weights of the so-called elements conform with the supposition, but the researches of Dr. Turner discovered no foundation in nature for such numerical concordance; and now he seems to suspect that hydrogen and heat are the sacred pair. In fine, there is not a young chemist of any ardour of hope, and at the same time prone to divination, but flatters himself he can reduce the scale to two; and that quite independently of the speculations of others. I remember that when I attended the elegant prelections of Professor Hope, ten years ago, I satisfied some fellow-students, by a kind of algebraical computation, that five was quite a sufficient number of simple bodies. So much for that irresistible yearning towards unity which no one can forswear; and the fascinating power of an implicit error, when once it acquires a hold of the human mind, from which it is the right of every man to be set free. Some may suppose that too much has been made of what I have called the *al*-chemical element of the middle-age chemistry, and represented as inherited from Demetrius of Abelæa; but if so, I only rob myself, and

there is no Divine law against so pious a theft. At all events, it seems to be established by the results of history, on ground quite apart from this, that the greater positive truths of which the higher theory of nature is eventually to be constructed, first appear as mirages among the purpled morning clouds, casting down their shadows during a grey afterdawn, and hovering about the long unsettled horizon of human thought, often in most questionable guise ; but noon reveals the coming form distinctly on the verge, and the predestined craft shall sail up and over until, ere the evening of man's day of work, it reach the shore, awaited with the timidity of hope, and fraught with the wealth of invisible climes.

LECTURE IV.

[THE larger portion of this fourth Lecture was devoted to details of processes bearing on the practical illustration of the hypothesis, and to repetitions of such of them as admitted of being gone through in such circumstances. All this was of course extemporised by the lecturer, and does not appear in his manuscript.]

Hitherto we have looked at the experiments of which all this is said in the light of the mental initiative which conducted to their performance. Suffer me to draw three conclusions from them *a posteriori*, before proceeding to the consummation of the whole subject in the construction of a universal definition of the science to which they belong. In the meantime, the double evidence of analysis and synthesis is necessary to the determination of the constitution of compounds, as distinguished from their composition, and synthesis is the better criterion of the two.

I. No compound can be regarded as composed of the elements it yields to analysis, unless it can be reproduced by their synthesis. Cyanide of mercury, reduced at lower temperatures, and under one atmosphere, is resolved into mercury and cyanogen; whereas at higher temperatures, and under pressure, the products of its decomposition are mercury and paracyanogen; but cyanide of

mercury can be prepared by synthesis, and therefore is a true cyanuret. But take the ultimate analysis of cyanide of mercury: by one process it is made to yield one equivalent of mercury, two of nitrogen, and four of carbon; and, by another, one of mercury, two of nitrogen, and one of silicon.* Now, it has been shown that an intermediate step of the latter process is the production of paracyanogen, which is a real cyanide of cyanogen, because it is made by the synthesis of two cyanogens, and cannot be resolved into two cyanogens again, the chemical union of equal and similar atoms being indissoluble; but paracyanogen was never made by the synthesis of nitrogen and carbon, and it may be made to yield silicon as well as carbon, so that its constituent cyanogens are to be regarded as only hypothetically composed of nitrogen and two carbons. This does not, however, affect the *rationale* of the constitution of silicon; for although paracyanogen may not contain carbon as such, it certainly includes its factors or coefficients. This exception excludes every ultimate analysis which has yet been made in the chemistry of bodies of organic origin. It does not, indeed, affect the *proximate* analysis of such substances, nor the fine generalisation of Liebig regarding the proximate constitution of organic matters, but it proves that the constitution of the compound radicals themselves may be a far deeper secret than he has imagined. The prussiated alkali is a compound of potassium and cyanogen, but cyanogen is not necessarily composed of nitrogen and carbon, one or

* When these lectures were delivered, Dr. Brown believed himself able to demonstrate, by fully successful experiment, the isomerism of carbon and silicon. Waiving all discussion of this point, the reader is requested simply to admit them as a hypothetised possibility, here assumed with a view to illustrating the practical bearings of the general conception.

both of which may be products of transformative decomposition. Indeed the carbon, oxygen, hydrogen, and nitrogen, which have been extracted from organic bodies, *may often be* mere products of transformation, and if the results which have been described do not render this extremely probable, they certainly demand a proof of the contrary.

This reflection thus sheds a visible, though an uncertain and somewhat confounding light on the remarkable fact, that although chemists have analysed thousands of organic proximates, and concluded from their results that they are all composed of the elements of water and air, they have never produced a single substance analogous to even dead vegetable and animal matter from truly mineral elements. The elements which are yielded to analysis by sugar, starch, and gluten, jelly, fibrine and albumen, all abound in the air we breathe and the water we drink; and yet, on the one hand, our bodies cannot be sustained by water and air, and, on the other, the analyst is unable to produce these nutritive principles from their apparent elements. Let the hope be entertained, that this attempt to remove a dogma which has all along been taken for granted, and to point to the probable source of truth in the important inquiry, may eventually lead to the discovery of the true (and not the merely equivalent) constitution of organic proximates, and the consequent invention of an art of imitating the processes of the vegetable and animal kingdoms so far as these are merely chemical.

II. The occurrence of silica in the epiderm of the *Arundinaceæ*,* and especially in the articulations of cer-

* This particular illustration may certainly be questioned, on the ground that it is more than doubtful if, in soils *entirely* deprived of silica, these *Arundinaceæ* can or do form their silicated envelopes. It is, however,

tain of such larger reeds as the bamboo, taken in connexion with the insolubility of sand, has attracted the curiosity of the botanists, and given rise to an interesting question which is by no means set at rest by the observation of Berzelius, that silica is slightly soluble in water, for it only applies to the hydrated, unignited, and nascent conditions of that body, in none of which it appears to be presented to the growing plants. Again, the silicated character of many petrified woods, shells, and other organic remains, found in circumstances in which the source of silicon is by no means apparent, has originated discussions of a high order among the geologists; and, in August 1840, the Committee of the British Association assigned a grant of money for the institution of experiments designed to elucidate the subject. Now, the fact that carbon may be converted into silicon by chemical processes of a kind, the conditions of which are very likely to be found in the circumstances in question, ought to form one element of such an investigation, and may conduce to the solution of the problem. It is quite possible that many obscure points in the chemistry of organisation and disorganisation may be placed in a clear light by the application of this clue; many able physiologists having lately maintained, in the face of the conclusions of the modern chemistry, that the organic powers of the several kingdoms of living creatures do

allowed to remain as the type of a multitude of analogous facts in the vegetable world, of which no explanation in harmony with the existing chemistry has yet been educed. And even in the special case selected by Dr. Brown from among these, it is perfectly possible that his supposition may yet prove to be the true one; for it has yet to be shown that an amount of silica *as such* in the soil is required, equal to that which these *Arundinacæ* elaborate from it. This has been in all such cases assumed; but facts are not wanting that, to the unbiassed mind, call the assumption very sternly in question.

produce elements from bodies which they have not been suspected to contain. Although there is no doubt that many laborious investigations must be made, and many years elapse before this application of transcendental chemistry to the illustration of geology shall be possible, in all its generality, yet the geological relations of carbon and silicon are striking enough to afford a trustworthy earnest of future achievement.

III. These researches confirm and set the stamp of very strong analogy, on the hypothesis which I presumed to lay down on more questionable ground in my former lecture. That conjecture may be expressed in these four propositions: 1. The fifty-five elemental forms are all compound; 2. They are compounds of equal and similar atoms, so that it is within the scope of natural possibility that they may all be derived from *one* generic atom; 3. The fifty-five are the interrupted links of a chain which is not straight, but probably a network wrought into the form of a cone; 4. These links, even as they are, naturally fall into isomeric groups, like the following:—Oxygen, sulphur, selenium, tellurium; carbon, boron, and silicon; fluorine, chlorine, bromine, and iodine; and so on. The only essential part of this hypothesis is the supposition that the elements are compounds of equal and similar atoms; and it not only cannot be established but by actual trial, but it is eminently susceptible of the test of experiment. However, even in its speculative form, it illuminates all the science: 1stly, It explains at once why the elements, though compound, cannot be decomposed by heat, chemico-polar induction, and chemical reaction, which appears to be identical with the latter force; 2dly, It renders the atomic disposition of the solid element of the electrolysed circle easily understood—a desideratum which has been ably

pointed out, and ingeniously evaded by Professor Graham. Copper or zinc or other solid conductor is represented as $x + \overset{\text{negative}}{\chi}$, $x + \overset{\text{positive}}{\chi}$, $x + \overset{a}{\chi}$, or $\overset{a}{y} + \overset{p}{\gamma}$, $y + \gamma$, $y + \gamma$; and so on. Chemico-polar induction has place, but there is of course no decomposition of the metals, as is the case with the electrolyte compound of unequal elements in the cells, water, hydrochloric acid, or salts. In fine, every reflecting chemist must observe the facility with which this hypothesis accounts for the relative physical characters and chemical properties of the members of the different natural groups of elements, whether they be associated on the principle of isomorphism, or this of isomerism, and reduces all the multiformity of constitutions to consummate simplicity.

Let us now pass abruptly to the promised definition of chemistry.

I. On the doctrine of atoms, as a hypothetical premiss, approved to be formally legitimate on the score of natural possibility, by the analogy of astronomical facts, and raised almost to the sufficiency of a true theory of nature, by the multitude of observations which it renders intelligible, may be erected a philosophical definition of chemistry, which, both in the general view of it, and in all particular instances, may be rendered either practically for actual experiment, or fictitiously for abstract speculation.

II. Chemistry is the science of atoms, and as such contemplates atoms, *first*, as existing in objects occupying space; and, *second*, as agents in phenomena taking place in time. The statics of chemistry seeks to discover the constituent simpler atoms of all compound atoms, and the laws of atomic constitution, chemists conventionally regarding all such atoms as they are unable to resolve

into simpler as, for the time, simple or elementary. Phenomenal chemistry discovers the motions of atoms in the processes of combination (position) and decomposition, and in the state of equiposed constitution; and the general laws of those motions. Thus, meaning by the word *atoms* those homœomeric parts of which sensible forms are assumed to be made up, chemistry is that science which determines the constitution of atoms, and the phenomena attendant both upon *the state of combination*, and the two antithetical processes of atomic analysis and synthesis. This definition states the two great divisions of chemical inquiry laid down by Bacon, under the heads of the *schematismus corporum*, and the *processus à latente*, and includes the whole scope of the definitions of Berzelius and the modern chemists; *but it contains a great deal more*. It represents the phenomena attendant on the *state* of combination as the first objects of chemical dynamics. The phenomena attendant on the state of combination in the solar system are those intricate internal revolutions of the constituent globes of that system which the modern astronomy has unravelled. The analogous phenomena in a compound atom, or atomic system, do not manifest themselves directly in experiments; for every chemical experiment is intended to disturb that state of equipoise in which they take place. So far as I know, nothing exact has ever been written on this subject; yet it will be found that the results of modern chemistry have furnished data enough to proceed with the superstructure of that primary department of the dynamics of the science.

ESSAYS

TOWARD

THE CRITICAL HISTORY OF CHEMISTRY.

I.

THE ATOMIC THEORY BEFORE CHRIST AND SINCE.

(WESTMINSTER REVIEW—[Vol. lix. No. cxv.]-New Series, Vol. iil. No. i.)

THE progress of science is as orderly and determinate as the movements of the planets, the solar systems, and the celestial firmaments. It is regulated by laws as exact and irresistible as those of astronomy, optics, or chemistry; although the weather of our changeable English atmosphere may not appear to be more fitful and capricious, that is to say, at first sight and to the uninstructed eye. To put it more logically, both the uncrowded procession of nature, and the triumphant march of discovery, are the expression and the proclamation of the ideas or unwritten laws of development, which they respectively embody. It is only by a bold figure of speech, drawn from the sense of human freedom and fallibility before the unlied eye of conscience,

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that those phenomenal ongoings (of nature and science, namely) can properly be said to obey their several laws of evolution. Where it is impossible to disobey, it is also impossible to obey. Things do not, therefore, obey the law of necessity or omnipotence: they represent, manifest, incorporate, reveal, or show it forth; as the whole physiognomy of a man, could it but be understood, is nothing less than an express and admirable picture of "the spirit of a man that is in him." Be the worth of this distinction in the present connexion what it may, however, it is assuredly a centred and standing law that the very opposition, which is always being offered to the advancement of truth, whether by uncongenial circumstance or inconsiderate man, is overruled by principles as fixed, if not yet so calculable, as those disturbing forces that systematically retard the flight of Encke's comet, or drag big Neptune from his solar orbit. Both the new investigator and his hinderers may rest assured, that they unconsciously conspire at once to hasten and to steady the career of science. The discoverer, in good sooth, who knows this so truly as to live on the belief of it, as the religion of his inquiring soul, annihilates obstruction and enmity. Everything is then propitious to the fulfilment of his vocation: his own defects, his exaggerated single faculty, his unprovided wants, perhaps his Nessus' shirt of a bodily organisation, evil days and evil tongues, and all the elements of seeming ill, are on his side: his proud oppressors are nowhere to be found, for all men are his friends, although they know it not!

One of the deepest of those laws, which are expressed, as has just been said, by the history of scientific conquest, arises out of the constitution of the mind itself. It has been illustrated with equal generality and pre-

cision by Comte the Positivist. According to that vivacious, far-sighted, and muscular critic, there are, and in a manner must be, three principal epochs in the growth of each science, and of all the sciences together; the childish Religious, the boyish Metaphysical, and the manly Positive epochs of development.

It needs scarcely be added that this great writer considers the positive or Baconian era as the consummation of all inquiry; and thinks the method of discovery by observation and induction the perfection of philosophy, destined one day to carry humanity to the heights of attainable bliss. It must be avowed in passing, and merely avowed, that this appears to be at once an error of fact, and a breach of the very methodology which is exalted. There is surely a fourth epoch of scientific method beginning everywhere to dawn upon the world. It is preparing, as we have been accustomed to think, to combine the descendentalism of Plato and the idealists, with the ascendental processes of Bacon and the sensationists, and likewise to render the long-awaited union worthy of mankind, by shedding into it the spirit of Christ and his disciples. As a fine generalisation of the past history of the purely ascendental sciences, however, the doctrine of Comte is most important and interesting; and it will always well repay the private labours of the task, to trace the evolutions of the law in the genesis of any science in particular, or of the sciences considered as an organic whole. At the same time, it cannot be inexpedient to warn the English student that the word Metaphysical, as applied by the French discoverer to his second epoch of development, is objectionable on several accounts; but mainly because it conveys a sneer at one of the sciences of which M. Comte is ignorant, and at a kind of thinking alien to the nature of his

limited individual mind, but not therefore beyond the pale of human study. Hypothetical were a better epithet: for, certainly, hypothesis is no part of positive science; and hypothesis did constitute the soul (not the body, take notice) of every present inductive science before it grew altogether positive. Yet hypothesis, logically wielded, is a potent instrument in positive science. The sternest positivist may readily be the greatest of hypothetists; and he that runs may read the fact, for it is blazoned all over the Book of the Chronicles of the kings of our Israel. Copernicus, and still more emphatically, if not obsequiously, his editors, Osiander and Rheticus, put forth the most memorable of works in modern positive science—the *De Revolutionibus*—as a hypothesis or possible view of the subject in hand. Newton wrote, *hypotheses non fingo*, on the *Principia*; but neither was he slow to assert that ‘no great discovery was ever made without a great guess.’ It was the canonising of a profane hypothesis as a sacred fact, that was, as it still is, the vice of the second epoch of scientific life. A metaphysician might therefore have called it the suffictitious epoch; the day of the placing of figments underneath the seemings of nature, in order to the apparent understanding of them; or, more simply, the fictitious stage of the growth of science. But how much more offensive the assignation of the blessed adjective Religious to the first crude, polytheistic movements of the scientific spirit! To be brief, since the subject is really beyond our present bounds, this historical speculator’s three ages might have been distinguished, by a more reverent and affectionate critic, as the Superstitious, the Fictitious, and the Real.

The order of succession, in which the natural sciences (for here is no question concerning logic and the mathe-

matics, much less concerning philosophy proper) have made their appearance in the course of human progress towards Paradise Regained, has largely depended on the relations of their several objects to the person and resources of man; that is to say, considering such succession as a thing quite apart from the internal development of those sciences, taken severally or together. The parts of nature are not equally near, nor yet equally accessible to him, standing on this planetary orb and beholding the sun and moon, nay, the vast majority of things, deploying before him according, not to the truth of even phenomenal reality, but to that of mere seeming. Seeing nothing as it really is, but on the contrary everything nearly upside down, as if he were standing on his head, it behoved him to grasp at anything in the beginning of his scientific existence. Thus the mechanics of those palpable forms, which more immediately surround and withstand or help him, was naturally brought to something like perfection—always meaning perfection of method, not of invention or application—before it was possible to apply the same instrumentality, as had been brought to bear upon such problems with success, to the distant and majestic mechanism of the solar system. Even so lately as the time of Newton, the sublime divinations and hypothetical demonstrations of Kepler had to be postponed, by a stricter logic, to the celebrated mechanical experiment, which yielded both the idea and the ratio of the law of gravitation. That memorable apparatus, with the seconds' pendulum and the falling weight, was nothing less than the desiderated fulcrum of our own Archimedes, who lifted the astronomy of Copernicus, Galileo, and John Kepler with his lever, and placed it once for all where it now rests for ever. It was after the develop-

ment of mechanics, and through the mediation of a mechanical experiment, that the Copernican system became the model of knowledge, capable of indefinite growth, though not susceptible of essential change, consummate in method, unfinished only in extent, a perfect science, and the only Work without a Peer* in all the world of modern discovery.

It was just as naturally that chemistry followed in the train of physical astronomy. Long before Dalton it had been apprehended that the constituent particles of the sensible forms, at least of planetary, or rather of accessible matter, are in reality the agents and the patients of all chemical mutations, notwithstanding the apparent phenomenon of mass incorporating with mass. Newton—not to mention the abstract hypotheses of Leibnitz and Boscovich, who were not veritable chemists like our discoverer,—Newton himself, after having risen from experimental mechanics to astronomical computations, came down with all the swoop and force of analogy upon the interior nature of those sensible forms, from the dynamical laws of which he had mounted to the theory of the solar system.† He conceived that the chemical propensity of one body for another consists in the attraction of the particles of the former for those of the latter ;

* Stahl inscribed the *Physica Subterranea* of Beccher with the lofty phrase—*Opus sine pari*. And, certes, it was as wonderful a piece of creation, half brought out of its chaos, as the history of science can show : but the Copernico-Newtonian astronomy is of another order of thing !

† It seems to be understood that those Newtonian MSS., which were burned by the overturning of a light, contained the results of prolonged experimentations in chemistry, the reigning monarch of astronomy having even dared to dream of conquests in that new world, of such a nature as is scouted by the generality of chemists of this present generation. Was anything lost in these flames ? To say Yes, were to arraign Providence, or, at least, the *harmonia præstabilitata* ; to say No, were almost to insult the memory of the astronomer-chemist.

pair by pair, like the earth and the moon, or one with more, as Jupiter and his satellites ; and also that, when a compound of two bodies is decomposed by the coming of a third into the field of action, it is because the particles of the new substance are more attractive of one and more repulsive of the other original constituent, than these constituents are attractive of each other, and than one of them is repulsive of the intruding body. It is a question of attractions and repulsions : the contest lies betwixt the sum of one attraction and repulsion, and the sum of another such pair of forces : the victory is decided by the mere weight of numbers, representing amounts of force. Such was Sir Isaac's theory of chemistry : and it needs only be added, that this is the origin of that tenet of the Lavoisierian chemistry—more expressly brought out by Fourcroy, but still implicitly held in the science—which identifies the attraction of cohesion between equal and similar particles, such as two sulphurs, and the attraction of affinity between a pair of unequal and dissimilar particles, such as a sulphur and a hydrogen, the constituents of hydrosulphuric acid. Be that tenet the truth of nature, or one of those misconceptions which are so often permitted at once to speed and to check the progress of human science, such was Newton's notion of affinity in those early days ; but, so far as can now be known, he made nothing of it as an organon of discovery. The master of astronomy and the creator of optics, he does not appear to have done anything for concrete chemistry, his laboratory notwithstanding ; always saving and excepting his conjecture that the diamond was combustile because it is a strong refractor,—a prosperous guess which it is customary to extol as sagacious, in spite of the notorious fact that there are stronger refractors than that crystal-

line carbon, which are not combustible a whit. Its combustibility has no connexion with its refractive power, in fact: and, though the hypothesis was not atrociously inconsequent when it was made, it is as ridiculous as illogical to admire it now. It was just one of those countless little strokes of fortune, which are constantly befalling the man of genius and industry. In the game of discovery, long and difficult though it is, Nature always gives her darling loaded dice, because she will have him win the day. But Isaac Newton has almost become the mythical man or demigod of British science, owing partly to the assault of Voltaire, partly to the lofty rhymes of Thomson, partly to the clangorous eloquence of Chalmers, yet chiefly and all but entirely, to the overwhelming conceptions with which his very name amazes the mind: and one of the consequences is, that all sorts of trumpery stories about falling apples, as well as every kind of encomium, may be heaped with impunity on the Atlantean shoulders of 'the incomparable Mr. Newton,' now that the shade is divinised. If *nîl nisi bonum* is to be written on the tomb of the vulgar dead, after all; what shall men not say or sing, if so please their uncrowned majesties, at the shrines of the immortals!

The discoveries of the astronomers suggested to Torbern Bergman—better known now as the discoverer of Scheele the discoverer, than by anything he achieved in chemistry, yet a much-accomplished man of science—the thought of applying the mathematics to the illustration of chemical movements. Could not the relations of those orbicles of matter, called atoms or particles, be measured and assigned by geometry, in the same manner as the relations of those orbs called heavenly bodies or globes? The same question occurred to Buffon: but

both the Swedish chemist and the French naturalist abandoned this monition of their genius as impracticable; and that for the same so-called reason, namely, because they supposed (not knew, but thought they knew) that the particles of sensible matter, say of a stone or a water-drop, are so vastly near each other, though demonstrably not in contact, as that their shapes come into the geometrical question, and vex it with hopeless perplexity. In connexion with the mineralogical theory of the day, the shapes of particles were deemed to be as numerous as their kinds, and as picturesque as the crystals in a museum: so that it was an anachronism to speak of atoms as orbicles in the last sentence, but it was intentional; for it is our present business, as it is our pleasure, to strip these things of their technicality, and to present them in as broad and human an aspect as possible, for the sake of the stranger in those realms of study. Let it be clearly understood then, that it was not till such conceptions of the material forces, as had almost kindled Bergman into another Newton, as has just been seen, had been fairly shed into the scientific mind of Europe, that chemistry was able to assert itself with effect and emphasis, as a member of the Holy Alliance of the Positive Sciences in Europe. Scheele, Priestley, Cavendish, Black, and LAVOISIER, were the successors of Sir Torbern and his feckless compeers; and, ever since their achievements, their science has grown bigger and bigger with unborn progeny. Every ten years or so, it gets more deeply inwrought with the greater interests of mankind. Already it creates endless manufactories; already it tills the ground: and it prepares to cast its light into the subterranean physics (to borrow the title of Beccher's chaotic Opus) of geology, and into the still more secret physics of physiology, pathology, thera-

peutics ; all its gifts and promises being, even ostentatiously, fraught with practical benefits and intentions. In short, notwithstanding the prowess of Herschel and the astronomers, or of Cuvier and the naturalists, and notwithstanding the presence of such questioners as Maedler and Owen, chemistry is the science of the century ; and that, not by any means for what has yet been done or conceived in it, nor yet for the unprecedented conquests which the chemists are making ready to attempt with success, but because there are sciences at work, which cannot advance a step farther, we do not say in mere breadth, but in depth, until this eminently terrestrial yet cosmical and ideal science be carried nearer perfection.

Of such sort, then, is the circumstantially determined succession of the sciences ;—mechanics, astronomy, chemistry. It is not our cue to trace this part of scientific history more curiously, as, for instance, to show the circumstantial relation of optics to mechanics and astronomy ; nor to follow it any farther up, as by exhibiting the dependence of physiology on chemistry, of psychology on physiology, and so forth, until the full development of the natural, and partly natural sciences, at least in method, shall render it possible for philosophy to evolve a many-sided doctrine of man. These illustrations will suffice for the indication of this second and more superficial, but equally unfailing law, of the history of science. It is a third and still more interesting historic law, connected with the origin and growth of many of our modern ideas in science, that the Atomic Theory brings into view.

It is certainly the most provocative and wonderful thing in the history of positive knowledge, that many of the best results of modern science were anticipated, some

four or five centuries before Christ made the methods of such science a practicable possibility, by the physiological and other schools of Greek or Egypto-Grecian philosophy. They did not, indeed, propose to draw forth some precious and unheard-of combustible airs from the olive-oils of their country-groves, and send them all through Athens in a system of arterial tubes, to illuminate the city of Minerva when Dian should be resting from the labours of the chase; nor to cross the Hellespont, or tempt the broad *Ægean*, in fantastic barges rowed by fire and water; nor to whisper words of amity to their allies, defiance to their enemies, swifter far than the flight of a dove to her mate, through the invisible hollows of a copper-wire; nor to dash strange metals out of marble and natron by means of subterranean levin-brands, filched from the carriers of Vulcan on their way to the heaven of Jupiter Tonans; nor to make a hundred complex calculations of the disturbing forces exerted by one huge planet on another; nor to go and seek another hemisphere, or make experiments with electron at the North Pole; nor to dig extinguished worlds of animation from the laminated hide of the old Earth; nor yet to sprinkle the ground with urine and the far-fetched dung of sea-birds. It was never in the divining, the excavation, and the intellectual manipulation of the concrete facts of nature that they came before, excelled, or even equalled the men of renovated Christendom. In the art of experiment, and in trying to find his way with untripped step among details, the Greek was as feeble as a child: whereas in the sphere of ideas and vast general conceptions, as well as in the fine art of embodying such universals and generalities in beautiful and appropriate symbols, it is not a paradox to say that he was sometimes stronger than a man. Could old

Leucippus, or Demetrius of Abelaëa, or, better still, that vagabond philosophical quidnunc, Apollonius the Tyanæan, be resuscitated now, carried from Vienna to Paris, from Paris to metrocosmical London, and shown all the contents and ongoings and aims of their myriad museums, laboratories, observatories, studies, libraries, and officinums, the antique scholar might well be as much bewildered and overawed as any African convert, or steadfast Indian chief, fresh from the wilds. But let some all-eloquent Coleridge, or logical Hamilton, or, better still, some all-conceiving and ideal Goethe, take the venerable Ghost to his quiet chamber, and there expound the fundamental ideas and largest conceptions of all those arts and sciences, perhaps beginning at the Atomic Theory, or the law of Polarity, the Ancient might break in on the discourse, profess he knew it all before, and vanish contented to his early haunt. Not that all the broad and general conceptions of positive science were foreknown, and therein predicted, by pre-Christian thinkers and seers ; but so many of the capital points of modern theory did actually constitute principal elements of the Greek idea of nature, as to arrest and astonish the historical inquirer at almost every turn ; and it is really not wonderful that our fonder Hellenists, living with reverted eye upon the men of that most fascinating past, and refusing to be comforted because they are not, swear like insulted lovers at the present unoffending age, and claim all our discoveries, forsooth, for the silent gods of their idolatry. The peculiar circumstance attending our rediscovery of their old truths, is the fact of our having reached the summits in question by a long course of observation and strict induction, climbing every step of the ascent slowly and surely, while they sprang to the tops of thought

at one bound, from the standing-ground of the most obvious facts at the very foot of the mountain-range set before them and us. Be the nature of this difference, and of all its results, what it may—and the secret will be opened in due time—it is certain, always speaking in a very general style, that the whole fabric of inductive science was drawn out in high-going, wide-flowing outline by the earliest masters of conscious thought; the task of filling in all the multitudinous parts, and co-ordinating them into one living temple upon the world-wide basis of experience and common sense, was left to us. Happily, the immense labours of our modern method are accompanied at every step, richly compensated and even glorified, by the most marvellous discoveries of every kind, else its noble toils might have been too great for mortal man to undergo. It takes fourteen years to make out a new fact that is worth while, said a living chemist of the true Baconian genius, on an occasion in point some years ago; and every discoverer in the world, whose wealth of experience is not of yesterday, would assuredly indorse the note;—but what a strange contrast does the thing present to the swift improvisations of those patriarchal grandsires of the present race of inquirers! The maximum of concrete labour and working talent, with as much genius as can be—is the formula of the latter: the maximum of genius and daring, with as little experience as possible—was that of the former. For example, Democritus and Empedocles foresaw those things at once, but it was “as in a glass darkly,” which Dalton and Faraday, or rather large companies of craftsmen represented by these great names, have slowly and painfully brought out to the surface, flooding their every secret part with the blessed common light of day: and now they are as minute and true as a

daguerreotype, without losing a single line of their old grandeur of aspect. The reference is made, in this instance, to the four elemental forms of material manifestation—solid, liquid, ærial, and imponderable or dynamical ; and to the Atomic Theory of the three sensible forms of such manifestation : nor could a better illustration of the species of historical nexus now under discussion—namely, that which subsists between the divinations of the Egypto-Grecian foreworld, and the generalisations of the Christian afterworld of human science—be anywhere found than the history of this Atomic Theory in its two movements, before the coming of Christ, and since that Beginning of Days. After a quick glance into the idea of that Theory, as it made its appearance on those fertile shores where Apollo, being a god and the son of a god, condescended to men of lowly spirit, and kept the sheep of Admetus, making music as he went, we may consider it to more advantage in its outward developments, now that it has sprouted anew, grown up as wondrously as the mustard-seed of the parable, and spread far and wide over the cultivated fields of Christendom.

It would appear that some sort of doctrine, conceiving of sensible matter as being produced or constituted by the concourse of substantial or underlying atoms, not touching but moving more or less freely about one another, was very early promulgated among the ancient Hindoos ; and that in logical opposition to the extreme Idealism which has always predominated in the East. If the opinion of some critics be correct, that the monads of Pythagoras were endowed with corporeity or bodily presence, it is probable that a similar tenet was discussed by the initiates of the old Egyptian mysteries also ; and

that, it is almost certain, in the same antithesis, namely, in contest with that inborn Idealism, which has never been able to die out of the world of speculative thought, notwithstanding its doing such violence to the common notions of us Christianised, western, and world-subduing Teutonic tribes, as to take all the phenomena of nature for nothing but the co-instantaneous shapings of the spirit.

That aspect of the atomic theory, however, which is under view at present, originated in the sceptical and penetrating soul of Democritus, the successor of Empedocles in the physiological, or second movement of Greek philosophy,—if the reader will permit the whole effort of that national intellect, from Thales down to its dual consummation in Aristotle and Plato, to be dignified by courtesy with that aristocratic and all-exclusive style and title. It was the teeming head of Democritus that first conceived the proposition, for instance, that a pebble from the brook is not a blank extended substance or dead stone, as it seems to the bodily eye, and as it always remains to the judgment of common sense, like the yellow primrose of Peter Bell; but a palpable thing, resulting from the congregation of multitudes of atoms, or particles incapable of being broken to pieces, as the stone is broken when dashed against a rock, or worn to powder by friction with its neighbours. It was the secondary, but co-essential half of this definition, that these co-aggregated and constituent atoms of the stone are not in contact with one another, albeit that human eyesight is not fine enough to see the spaces between them. This marvellous view—for marvellous it was and still is, although now as trite as the dust under foot—was probably the lineal offspring of his earlier thought, to wit, that the Milky

Way (hitherto sacred to the white feet of down-coming gods and heaven-scaling heroes) is no blank extensive show of far-spread light, but the unique result of multitudinous heaps of stars, so distant and so crowded in their single plane of vision—though as free of one another as kings, in reality—as to render the interspaces undistinguishable by the sight of man or lynx. The astronomical illustration of Professor Nichol applies to the crystal-stone as well as to the firmament:—Across some great American lake, the farmer is accustomed to see the mass of forest over against his log-hut as if it were some vast and silent and solid shadow on the shore, ‘some boundless contiguity of shade;’ but he knows, with the same certainty as he knows his homestead, that it is in reality a vast, clamorous, and unresting assembly of trees, standing respectfully apart. Democritus had possibly also observed how the common stars of night are brought out into visibility, even on the mid-day sky, when looked at from the depths of a pit; and one might venture to suppose this to have been the origin of that famous proverb of his, in which truth was represented as lying in wait at the bottom of a well. Such, at all events, and so truly sublime as well as true, were two of the great conceptions in which the disciple of Leucippus showed the lucidity with which he had seized the perceptions of his master, that the truth of appearance in Nature is not the truth of reality, and also that the latter has to be elicited from the former by the afterthought of science. It should be mentioned in this connexion, not only as not uninteresting, but likewise as illustrative of psychological tendencies, that the habit of bending his intellectual eye on the surpassing structure of sensible nature, landed this brawny thinker in a scheme of materialism, and of

organic necessity in the life of man. Standing in such a point of view, after having climbed (one might be excused for saying) the highest heaven of invention, there was nothing for it, of course, but to look with a light heart, if not with something like contempt, upon all the vicissitudes and poor struggles of humanity. It was thus he won and wore the questionable honours of the Laughing Philosopher. The great majority of his spiritual children and grand-children, down to the latest generation of them—for the type is as persistent as it is at once invaluable and one-sided—exhibit the same divided turn of mind, solemnity before Nature, and frivolity in the presence of the destination of man. Sadducees, Epicureans, utilitarians of every age, the larger proportion of modern physicians and surgeons, naturalists, mechanics, chemists, astronomers, physiologists, and students of every kind holding too close and constant acquaintance with the phenomena of matter, all display the same proclivity to Necessitarianism and light-heartedness. Curious and enthusiastic over a fossil fish from Agiochook, or an anomalous fly from New Zealand, and not irreverent towards the Deity or Divine Law of Things, they have small reverence for man, though ever ready to do him good in their own way, and much enamoured of his applause. For our own part, we cannot but think there is more of tragedy and pathos in such Democritic laughter of the light-hearted classes of the Commonwealth of Letters, even if the laughter knows it not, than in the weepings of Heraclitus, whose too afflicted eyes could descry nothing underneath the many-coloured canopy of human existence but matter for tears. The reconciliation of the more than Medea-and-Persian law of Nature, with the absolute moral freedom of that which is the highest in man, is a pro-

blem always soluble by faith, thank Heaven! but it awaits its scientific solution by a development of philosophy, now nascent, as we suppose, transcending both the materialism of the laughter-lover, and the idealism of the wailer, because combining the methods and the substances of those two polar and long antagonistic elements of a full-grown doctrine, at once comprehensive and humane. In any case, it were but sorry criticism to deduct from the fair fame of old Democritus on the score of his having been only the half of a man after all, seeing he was the half of an unprecedentedly great man at the least, and seeing none but fragmentary men have yet made their appearance in the story.

It is to be understood, then, in the meantime, that the Atomic Theory of Democritus for the most part stood in opposition, not to any form of idealism, but to the counter-tenet that the sensible matter of common experience is always to be considered as being infinitely divisible, and that by the very nature of those mathematical ideas or archetypes which stand embodied in creation. It was in conflict with the notion of the endless divisibility of material substances, also, that the buried and forgotten Atomic Theory was revived by the Cartesians; and, likewise, that Dalton suffered it to be placed by more than one of his earlier opponents, to say nothing now of his applauding judges and disciples, even of the latest dates.

The gist of the argument urged by the mathematicians against the Atomic Theory, as thus put in antagonism to the theory of the infinite divisibility, was just this:—Whatsoever possesses length, breadth, thickness—whatsoever has dimensions, in short—is essentially and mathematically divisible, that is to say, can be supposed to be halved, the halves halved again, and so forth for

ever; a thing most true, if only that had been the right method of considering the point under inquiry, which it certainly was not. The reiterated argument of the Atomicians, from Democritus down to Newton, was something like the following plea:—If the invisible but extant particles, composing the framework of sensible matter, were not adamant and perdurable, but divisible, they should wax old and crumbling, perhaps get cracked, and the nature of the bodily shapes depending on their agglutination be thereby changed; whereas air, earth, and water are as fair and full as ever. ‘Water and earth,’ said Newton himself, ‘composed of old worn particles, would not be of the same nature and texture now with water and earth composed of entire particles at the beginning. And, therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles, sensible bodies being apt to break, not in the midst of solid particles, but where those particles are laid together, and touch in a few points.’ It is the old argument, enlarged by the chemical and astronomical notions of ‘new associations and motions;’ and nothing but an argument it was, any more than the geometrical flourish just recorded for the thousand-and-first time.

The first thing that strikes the modern critic—no thanks to him, but all to his position, won for him by those contending predecessors—is the now patent fact that the disputants did not argue in answer to one another at all. The mathematicians came down, and that with a vengeance, from the idea of space to the fact of nature: the physicists struck right up from the fact of nature to the idea of space: and therefore they crossed swords without touching one another. A hit was impossible betwixt

them. Although they stood opposed to one another, they stood aside, and each fought his own shadow :—an easy foeman, because dealing no blows, and yet a troublesome combatant, being always ready to stand up to another play of arms. The sophistication of the mathematical heads is admirably put by Henry More, our own Platonising divine, in his book against Atheism : ‘ If a body be divisible into infinite parts, it has infinite extended parts : and, if it have an infinite number of extended parts, it cannot but be a hard mystery to the imagination of man that infinite extended parts should not amount to one whole infinite extension : and thus a grain of mustard-seed would be as well infinitely extended, as the whole matter of the universe ; and a thousandth part of that grain as well as the grain itself. Which things,’ slyly adds the quaint and puzzling Dominus, ‘ are more inconceivable than anything in the nature of a spirit.’

On the other hand, the mere special pleading of the physiologists (as they were denominated, without specific reference to what are now called physiological studies) is put an end to, as at once unnecessary and not to the point, by the more elaborated definitions of modern chemistry. An atom, if the unfortunate word be taken in its literal acceptance, is a thing incapable of being cut into, bruised, broken, frayed, or otherwise infringed upon ; an absolutely solid little nucleus, an incalculably hard kernel of infinitesimally (but not infinitely) small dimensions, an indivisible quodlibet : and that by the sovereign will of the Maker of it, or by the eternal necessity and fitness of things, according as you side with St. Paul or Lucretius. Such is now understood to be by no means the legitimate definition of a particle. Retaining the old and ever-venerable term, an atom

is a vastly little portion of matter never divided in the mechanical and chemical operations of nature, any more than a sun or a planet is ever divided in the astronomical processes overhead ; but by no means essentially or mathematically indivisible. Then there are compound atoms (or atomic systems), as there are compound stars or stellar systems,—the Terrestrial, the Jovian, the Uranian, the solar systems, and so forth. An atom or particle of marble is indivisible by any such mechanical instrumentation as is capable of dividing a piece of marble, made up as it is of multitudes that cannot be numbered of marble atoms. But present an atom of potassa to one of marble, and it is divided at once,—yet not into two pieces, only into its ingredient simpler atoms, viz., carbonic acid, which cleaves to the intruding potassa, and quicklime, which is set free. It is precisely as if some stronger planet were brought near enough to draw the moon off from the earth ; in which case the compound unit, called the terrestrial system, composed of the earth and the moon, would be decomposed :—only a poor little planetary artisan like man cannot mix up celestial systems, and heat the mixture in a furnace, or set fire to it in some supersolar atmosphere. Again, the particles of neither carbonic acid nor quicklime are simple atomic bodies. Potassa cannot divide an atom of lime, indeed ; but bring potassium (the metal of which potassa is the rust) into the atomic neighbourhood of quicklime, and its particle falls with ease into two simpler atoms, one of oxygen which unites with the potassium, and one of calcium (the metal of which lime is the rust or oxide) which is set free. Were it but known, beyond the reach of doubt, that the particles of the so-called elements—oxygen, sulphur, gold, and the rest of them—are really elementary or simple, it might be

worth while to confine the name of Atoms to them, and to call all compound homœomeric parts by the name of Particles, and perhaps all groups of particles by that of Molecules. But it is not known, nay, it is grievously doubted by many, and even plainly called in question by more than one good man and true; so that Atoms and Particles, if not Molecules too, must just be jumbled together in the current phraseology a little longer, at least until the dawn of a new day on the science. In the meantime, the proper definition of atoms is something like this:—they are invisibly small pieces of matter, constituting by their co-aggregation under the force of cohesion the sensible forms of nature, constituting by their combination under the force of affinity the compound particles of chemistry, and indivisible, in the sense of never being divided, by the forces which divide their aggregates and combinations. No sort of atoms or particles, how compound soever they may be, are ever divided in the mechanical operations of nature; and no simple atoms are ever divided by the powers of chemistry; whence the attribute of Indivisibility, as it is asked for them hypothetically and *a priori*, is lent to them on the credit of experience. Atoms are not essentially indivisible, but they are never divided; both the old parties were wrong, and both of them were right. They were severally right in what they affirmed, and wrong in what they denied,—an immensely frequent, if not an unfailing, double circumstance in the controversies of mankind. Enucleate the affirmation of almost any sect in any science, including theology and politics, and you have truth so far as it goes; winnow and catch its negations, and you have error. The process of elimination is often difficult, but it is infallible: and hence it is the deniers that are the do-nothings, marplots, and hinderers in this world;

happily as impotent a folk in the long-run, as they are evil-eyed, and maleficent for a time. For heaven's sake, now that Christ has come, and exemplified the blessed art once for all, let us see that we do not waste breath, heart, and brain, in mere denying any longer. Save every spark of the vital fire for your affirmations rather, that they may be strong and clear. But do not merely put your negatives in an affirmative form, and cheat yourselves, obstructing us. Never assert that Napoleon the Grand was the Emperor of France, if you thereby mean at the same time to deny that France ever had, has now, or ever shall have another as grand ! Do not swear to the infallibility of the Spirit of God in the Pope, Pius, Impius, or whom you will, if your oath mainly intends to deny the infallibility of that Spirit in any other Christian man. To come down from such high and mighty specialities to the neighbourhood whence we lifted ourselves up to them, do not affirm that your own experiments are right, if your purpose is just to deny that mine were as right as yours. It therefore behoves the true and completed man of science to lay down no exclusive propositions. On the other hand, he may withhold belief from the affirmations of another ; but he will do well to trample nothing affirmative under foot, to reject nothing with an empty No.

There are two things to be especially noted and pondered concerning this Pre-Christian Atomic Theory, before proceeding to that development of the idea of Democritus which has taken place during the last age of Christendom, and that more particularly in protesting England in the course of the present century. The first is the amazingly small basis of concrete fact on which it arose, or was erected. Leucippus, Democritus, Anaxagoras, knew no more than the most obvious things in nature,

that stand connected with the idea of the atomic constitution of matter. The easy rise of smoke, the easy motions of the air, the running of water, the yielding of wood under the wedge or the axe, the obedience of marble to the mallet and chisel, the resolution of combustible bodies into their four elements by fire, perhaps the expansion of material substances by heat, were well-nigh the whole array of those ancient instances. A handful of common mechanical facts, and a single chemical phenomenon,—and these standing in no scientific collocation, but mere matter of daily use since the world began,—constituted the stock of her philosophers; what an extensive *comparatio instantiarum*! Of the facts of the case, in sober earnest, they knew no more than the schoolboy or the helot. Moses and David, Solomon and Daniel, all the intellectual princes of Israel and Judah, knew as much: but they built no deep-going, sky-confronting, universal theory; because their proper genius had other and holier kinds of work to do. They had no bias, and not the gifts, for the discovery of second causes; their eye being fixed, as if by fascination, on the Personal First Cause of all causes and effects. If we of Christendom had disobeyed the call of our proper tendency and talents, and not gone on to learn ever more and more of the individual parts of our surrounding world by observation and experiment, the idea of the homœomeric parts of the visible creation would never have come into our work-a-day heads. Every great people, or cognate group of peoples, has its peculiar vocation or genius—for character is destiny—and ours was not to exemplify the primordial godward instincts of Humanity like the Hebrews, nor yet to seize the first principles of things by a process of hypothetical inference resembling divination like the Greeks; but rather to magnify the spiritual

insights of the former, and to work out the conceptions of the latter, by the slow and positive inductions of observative science, adding an indivisible element of our own, even the spectacle of humble and patient industry as of a good and faithful servant, followed by all the triumphs of specific discovery and invention. The Hebrews did one work for the whole world, once for all ; the Greeks did theirs also once for all ; and it becomes us, now that our turn has come, to conserve and assimilate the results of those national lives, in that which we are living, on our own and all future men's behalf. It is the plain indication of self-interest and common sense, not to ignore or waste the yesterdays of man's life ; and, in fact, the modern workman, how painstaking and keen soever, will never do a great stroke of work (such as Copernicus, or Cuvier, or James Watt achieved) unless he have imbibed much of the two past spirits of the world ; if not directly then indirectly, that is to say, if not in his own person, then through the personalities of other men, whether organically or by sympathetic contagion. In other words, it is the industrious son of Christendom, who is also a man of faith and genius, and he alone, that will now lead the world to new victories and its ulterior destination. The Bible penmen and the Greek masters should be the close companions of every man in this busy and distracting age, whose proud heart swells in silent places, when the spirit of science solicits him to go and once more demonstrate the Christian art of discovery to be a blessing, not merely to a nation or an age, but to all the whole world until the latest stroke of time.

The second thing about the old Atomic Theory, which must be remarked upon, is the completeness of its idea, notwithstanding its pyramid-point of a foundation on

the solid land of observation. It is complete in clearness, amplitude, height, mobility, and beauty. At all events, this praise is fairly due, when what it denies is blown away as so much airy nothing from its lucid affirmation. Matter is composed of atoms, not agglutinated, not even properly speaking in contact, moving vastly more freely upon one another than the visible molecules of the whitest dust on the dry sea-shore; not crowded and hurtling, but orderly and harmonious, not unlike the stars that constitute the Milky Way. A block of Parian is the visible form resultant from the co-aggregation of myriads of homœomeric or equal and similar particles of invisible marble, possessing all the properties of visible marble except such as accrue to it from their own co-aggregation, standing apart, ready to open to the edge of the chisel, prepared for separation in any direction, in readiness for every change. Why, the Conception explained all known phenomena in a trice; airy atoms giving way to every motion, watery particles flowing a thousand times more fluently than the finest sand, earthy or solid ones flying always away at the stout enough thrust or blow, and even the atomies of fire darting like spirits from the empyrean and back again:—and then, there lay the same Conception asleep during the long night of Hellenoid thought, ready to issue forth again at the chivalrous summons of Descartes the soldier, and confound the enemies of the mechanico-corpuscular philosophy; but readier still to obey the call of Newton and Dalton, the collegian and the schoolmaster, and pour its successive floods of light into the arcana of Chemistry, a science all undreamt of and impossible in the age of Grecian insight.

But a new day was already on the wing. Plato was both the Evening Star of this elder dispensation, and

the Morning Star of a coming twilight, being at once the Hesperus of the Socratic eventide, and the Phosphor of the Christian dawn. The Hebrew history, theocracy, and poetic pomp of prophecy, must indeed ever be held to constitute the true prelude to the New Testament narrative and ideology; but the marvellous manifestation of humanity, of which these were the dicotyledon or double germ, was a new dispensation unto more than one consummate national life and self-expression. First and foremost, its coming forth was the euthanasia of the Jewish life of intuition and worship, but it was also the apotheosis of the Grecian life of thought and art; for history has already shown in some little degree, and common sagacity is competent to foretell, while faith assuredly believes and knows, that it came to enlighten as well as to bless the world, else it shall have come and gone in vain. Be these things as they may, however, the Sun of Bethlehem at length arose. Destined it was to be soon obscured, indeed, after the loveliest rising the world ever saw; and then there ensued a long, long grey morning, of many dreary centuries in length, and sometimes deepened to almost the old Cimmerian darkness; but the twin elements of the new Solar warmth and light, love and knowledge, were never quenched, and now the affluent day has begun to glow around us with all its wealth of benefit and promise. Just such a miserable long afterdawn, only that its thick darkness was more meteoric and lurid, preceded the noontide of Greek illumination; and no man, whether friend or foe to the Lord of our unfolding epoch, must ever suppose that Christianity is a thing accomplished, or an experience fairly gone through, or that it has been a long time in the world. Compared with other great æons in the life of man, such as the Egyptian, the Oriental-Indian, and

the Greek, it is but begun ; and there is, therefore, little wonder that the ecclesiastical and civil polity of Christendom is yet a sorry chaos of conflicting forces, its arts crude, its sciences, including theology, unripe and divided, its philosophy divisive instead of mediatorial, and its life not divine.

The advent of Christianity is brought forward with emphasis, in the present unusual connexion, because one of the things, to our thinking, that puts a real difference of kind between Christendom and all its epochal antecedents in history is its being possessed by the idea of an organic science of nature, the very first condition of whose existence is unresting growth ; and therefore the man, be he ever so intellectual, who is too ignorant of the living anatomy of that characteristic fabric, cannot properly be said to belong to this age of humanity at all. Nor is it easy to conceive how such an embodied and substantial creature as cumulative science could have grown before our era. The seeds of scientific thought, indeed, were sown in the Greek period, and many of these germinated then, while certainly none of them did more than sprout into radicle and plumule ; but it has just been recognised above, that the seed contains the plan and anticipation of the whole future organisation. The full bringing forth of that organisation is a process which is now going forward in our presence ; and it required the soil, the atmosphere, the skyey influences of a Christian world of sentiment and thought, both before it could begin, and now that it is proceeding in the midst of us. It is a fact, that the Hebrews grew no ever-unfolding structure of positive natural truth. Even the philosophical and logical Greeks produced nothing but embryos, surrounding them with wonderful atmospheres of philosophical speculation ; in which they could and did not flourish ;

for these were not their congenial airs, and, like certain difficult but hardy germinations of the green-house, they awaited the day of transplantation. The Romans were as impotent as the Jews, and as impatient as the Greeks, in this kind of generation. In short, not only did not these three ancestors of life in modern Europe, but no nation of antiquity engendered a body of inductive science, growing from a multitude of germinal points into one vast living type. Not that the men of no other movement of human development, save the Christian evolution, were unobservant of nature:—far from that, for, in some directions, they some of them knew more than we. The inspired Hebrew knew nature as a passing show, not a true being, but only a transitory existence, contingent on the will of Him who is in that He is, as no other man has ever known it, save and excepting through his ministry. The Greek sage knew nature as the antitype and printed language of the ideal world, as we have scarcely learned to know it yet, notwithstanding his decrease and deathless legacy of thought in philosophy and art. Nature was better known in Old Egypt and the East as the very dwelling-place of the immanent God-head than ever in the West as yet, even since the teachings of St. John the Evangelist. Nay, to condescend on vulgar uses, Egyptian, Hebrew, Greek, Roman, to say nothing of the everlasting Chinaman, and all the other civilised or half-civilised peoples of the earth, have every one of them known just enough of nature for their instant wants, considered as the ready servant of the human upstart,—thanks to the venerable rule of thumb, as the practical, destructive, constructive, and self-providing instinct of the creature! From that unwritten rule, the common genius of the race, sprang the arts of roast and boil, wheat and grapes, bread and wine, malt and beer, threads

and webs, wood and stone, copper and iron, silver and gold, salt and sulphur, and a hundred empirical crafts, the scientific rationale of each and all of which remained an undesiderated mystery. But it was reserved for the tenth century of Christianity in Europe to initiate the art of serietic observation, pursued with a view to the explanation, as well as the subjugation of material things; and to the finding of truth as prior and superior to the invention of arts. Even when the inquiring, sceptical, and resolute mind of Greece laid hold on a strange and arresting fact, it made amazingly little of it. An old shepherd, as the story goes, found an iron-stone on one of his hill-sides in Magnesia, which he observed with astonishment to be possessed of a noteworthy property of attraction for iron and certain ferruginous bodies; but nothing came of the observation in those days, always excepting the title of an important Christian science. Theophrastus, his teachers, and his readers, were well aware that electron draws certain light bodies towards itself, after it has been rubbed a little on an appropriate rubber; but the science of electricity owes only its name to the Greek language. In contrast with this stopping point blank at the first step, no sooner does our Gilbert of Colchester (a man whom Galileo exceedingly admired and praised) take up the apparently sterile old fact, than the seeming stone approves itself an organ, and grows like a thing of life. By 1709, Boyle, De Guericke, Wall, and Hawksbee, have added to its enlarging substance. By 1733, Stephen Gray has descried that the rubbing of such a thing as amber calls something into manifestation, if not into existence, which travels faster than light, which some bodies suffer to travel through them untaxed and unimpeded, and which certain other substances will not convey. Next comes Dufay with his theory of two

imponderable fluids or propagations, and then Symmer discovers that friction always develops them both. The central fact of the nexus being thus brought into something like the freedom of scientific life, there soon follow electrical machines, Leyden jars and electrometers, piles and batteries, electro-chemical decompositions and the birth of potassium, the induction of magnetic polarity by galvanic currents, and the plucking of electric sparks from the magnet, not forgetting the comparatively early discovery of Franklin, that such electric spark, which takes place in the one-millionth part of a moment, is a flash of lightning and a thunderbolt in little—to trace the busy, growing, and surprising story no further.

The tenth century has been referred to as the initiation-day of this new spirit of the cumulative and ascending discovery of the veritable secrets of nature. Everybody understands, at this time of day, that the movement is to be dated neither from the Reformation nor from Francis Bacon. It is impossible to entertain too high an admiration of the broad, statesmanlike sagacity, the super-eminent forensic skill, and the fascinating style of the great ex-Chancellor's works on scientific methodology. But he was not the inventor of the method: he was only its noble spokesman; and he never could succeed in working the Organon he could so well describe. The method was no conscious device of long-headed speculators and easy penmen, whether Descartes or Bacon. It grew up spontaneously in the good heads, one might almost say among the busy fingers, of cunning and laborious men, long before their day; and the book of science would be but a mutilated, unintelligible bible, were all the earlier chapters blotted out,—its Genesis, its Exodus, its Leviticus, some of its grandest Psalms, and not a few of its most spirit-stirring Prophecies. It was not till

that instinctive method of the Christian workmen had developed itself to the full, after infinite pains and throes, amid disappointments and sorrows, always surrounded and often inveigled by perils on every side, that men of speculation and eloquence began to perceive and to drink into its spirit. It was only when it behoved it to find a voice and record itself, that it seized the massive understanding and the marvellous wit and fancy of the leisurely Lord Bacon, a man of small genius for discovery, but perhaps the greatest dialectician and expositor of his own or any other age. The thing sprang, and shaped itself, and began to change the world ; Descartes the Methodist, and Bacon the Organist, proclaimed its nature and its name, the former with subtlety and precision, the other with unparalleled worldly wisdom and the stateliest luxuriance of style ; and it has happened that the spokesmen of the epoch have well-nigh carried off all the honour and gratitude of posterity from the men of silent genius and constancy, who really brought it about. As for the Reformation, on the other hand, there is no need of looking farther back than Copernicus, the father, and certainly the most industrious, as well as the most daring, genius of Positive Astronomy, to see the fallacy of supposing that great movement to have been the beginning of inductive science ; for the long-suffering, silent, and creative Copernicus, was a faithful and most laborious minister of the Old Church. The Reformation was rather, in its intellectual phase, an effect than a cause of that spirit of active and inventive observation, accompanied by the plain inductions of common-sense, which began to manifest itself at all points—in Spain and the south, as well as in Germany and the north—as soon as the heterogeneous elements of Christendom began to settle ;

and the complicated nature of the case made it what still seems a long process, but what will assuredly be seen to have been wonderfully short when the world shall have been subdued, or even before the latter days of science. Doubtless, that effect became a cause as soon as it was produced, and the Northern ecclesiastical emancipation gave a mighty new impulse, not only to the liberation of theology, but also to every part of rational inquiry. In fact, no sooner was the inherent tendency of Christianity to burst into a characteristic scientific development brought to a head in the person and astronomical discoveries of the Polish canon of Wurmia, and the Christian men of the North set free from the residuary Paganism of Rome by his contemporary Luther, than the scientific mind of Europe sprang up with a rude excess of vigour, like the nearly-strangled giant Antæus when he touched the body of his mother the Earth ; and that, in truth, to the danger or inconvenience of some things which are foreign to its proper domain. In conclusion, it follows as a matter of course, from the major proposition now being pleaded, that the Lutheran, and every other reformation of religion that may have taken place, or that may be even now transpiring or making ready, is, and must be, propitious to discovery, precisely in proportion to the degree in which it has really brought out, or may yet bring out, the proper genius of Christianity, pure and undefiled. For our own parts, we are free to profess our opinion, that there is much to be done for Christianity, both as a discipline and as a theory of life, and much to be done for science, not only in extending its present boundaries, as all men know and say, but in lifting its aims, bettering its spirit, and developing its methodology. The more reformations the better, so they be done in honour.

But it was long before Copernicus, and mainly by faithful, though generally critical and often suspected sons of his ecclesiastical communion in its sincerer days, that the habit of inventive and necessarily endless observation, by way of experiment as well as passive watching, was contracted and cultivated for mankind. Yet it has first, by way of preliminary parenthesis, to be observed, that Moslemism is a lineal descendant of Judaism, though the bar sinister was figured on the shield with which it fought a highway for its crescent. It is a younger and a bastard brother of Christianity; the son of the bondmaid, not the child of promise; the Ishmael of the Desert; rude and simple; possessed by one of the central ideas of our common faith, namely, the unity and sovereignty of the Godhead; deeply tinctured with the morality of Jesus; and especially informed with the spirit of humility and resignation. Now, it was under the not ungenial, and in these respects almost Christian religion of Mahomet, that there came to life a sort of rude chemistry in Arabia. The oriental polypharmacy, indeed, seems to have been a fantastical jumble; not purely and magnificently theoretical, like the Greek doctrine of Four Elements, yet based upon the slightly experimental knowledge of a mere handful of chemicals; but, at the same time, it was practical enough to keep its votaries dabbling among reagents. The salt, sulphur, and arsenic of Geber, Mesue, and Averröes, at least belonged to the officinum; and they smelt more unmistakably of the laboratory and its operations, than did the fire, air, earth, and water of Empedocles and Aristotle. The latter were men of the solitary sea-shore, the silent study, and the gay academy; the former were at least practical physicians and eager druggists, if they were

also the most fanciful of thinkers. The genuine experimental spirit was astir within them, though they still maundered between sleep and waking, dreaming more than they saw. Their time was the orient boyhood of the new Man ; and, even in these days of positivism and matter-of-fact, the most fantastical and imaginative boy that ever blew up the kitchen chimney, or set fire to his bed-curtains, or smirched his face for life, is on the highroad to a gallant youth and a productive manhood, if only he has been fairly seized by the spirit and the habit of working observation and experiment ; being already nothing less than a true Arabian polypharmacist, capable of successively becoming a Roman Catholic alchemist, a Protestant chemist, and (shall we make bold to say ?) a Catholic atomician.

This Mahometan, or pseudo-Christian chemistry, was brought to Christendom, partly through Africa by the Moors, partly on the returning waves of the Crusade. It appears to have existed in Spain somewhat unprofitably by the beginning of the tenth century, under the Omniades ; and it spread to England, Germany, France, and Italy in succession ; having soon got inextricably mixed up with the subtleties of the scholastic or pseudo-Aristotelian philosophy, more especially with the notion of the elementary quaternion. Fairly christened on one hand, and transformed by the infusion of a scanty portion of the old Greek spirit on the other, it passed into the hands of an energetic, all-endeavouring, and most accomplished race of men ; the majority of whom were good and some of them even devoted Churchmen, a small minority having been daring and precocious sceptics. We do not now refer to the wretched brood of post-mediæval and post-dated alchemists, by whom the gallant age of alchemy

is yet represented in the judgment-hall of the vulgar criticaster of the present day ; but to an apostolical succession of mighty spirits in their day and generation. Our countryman, Roger Bacon, of Somersetshire, the author of the earliest wholly authentic works of this school, considered by Goethe to have been a greater man than Bacon the Second ; Albrecht Groot, of Suabian Bollstadt, commonly called Albertus Magnus ; his pupil, Thomas Aquinas, the Dominican ; Raymond Lully, of Majorca, supposed to have sat at the feet of Friar Bacon ; Arnoldus de Villâ Novâ, of Provence ; the two Hollandi, the Dutch compilers and commentators ; Basil Valentine of Erfurt, a Benedictine ; and even Paracelsus, the idol-breaker and revolutionary—were men worthy of any age and kind of human effort ; and they have been surpassed by no equal number of students in the history of science, in erudition, in force of genius, and least of all in industry. Industry was their pre-eminent virtue, and (with the exception perhaps of Paracelsus) it was industry in the laboratory ;—which is that lowly and victorious, new and altogether Christian, power now under quest and illustration. We have nothing to do—though full of sympathy—with their speculative views, but only with the triple circumstance that they had been smitten with the experimental passion, that they tugged and toiled like common day-labourers suddenly inspired, and that they dug a wonderful pile of rough-hewn facts out of the chaos set before them to quarry. All this authentic alchemical age transpired between the middle of the thirteenth and that of the fifteenth centuries. Bacon was born in 1214, Paracelsus in 1394.

The real alchemical school of Europe, having taken two hundred years to grow into authentic self-articula-

tion in the person of our glorious Friar, and having thus been done to death after a lifetime of two hundred years in and by Paracelsus, the scientific world, in the way that was leading towards modern chemistry, was divided between a shadowy host of mock-chemists, as nameless as spurious, and an honest, painstaking, unideal race of laboratory-men, such as Van Helmont (who had, however, alchemised in his youth), Cassius Libavius, Glauber, Agricola. The latter at length found a legislator and a leading idea in Stahl and the doctrine of phlogiston. But this is not the place for even a glance into the history of chemistry : and all that has to be insisted on here is done, namely, that the art and habit of the meditative, skilful, and deferential observation of nature in its arcana as well as its open parts, was the natural growth of even Pagan-Christian influences—a growth clearly prefigured and fitted, as the event has shown, to become the more and more strictly inductive system of our purer Christianity. In one word, the simple method of fact and common sense was initiated just as soon as the attention of Christianised thinkers was drawn to the theory of created nature. Fact and common sense is the formula of science : and all those alchemists and phlogisticians plead the cause of Fact ; all of them, by their practice and inarticulate course of life ; many of them in set phrase. Roger Bacon distinctly and loudly proclaimed the rights of observation ; and, in truth, his whole school of experimentalists were the accredited and natural enemies of the scholastic wranglers.

This short tribute to the workmanlike fathers of experimental science is happily no digression ; for it was in their direct line that the post-Christian phasis of the Atomic Theory arose. It is unnecessary to recur to the atomic views of the Cartesians, because they were dialectic

tical and discursive, not experimental and productive. Nor need we do more than merely remember that it was Newton who first put the conception of atoms into clear hypothetical connexion with the phenomena of chemistry. It was John Dalton that imparted enlargement, vitality, and fertility to the pertinent and memorable thought of the astronomer-royal of the world. That arithmetician described a principle of proportion lurking among the incondite mass of recorded chemical analyses, which had been accumulating ever since the introduction of the balance as an organ of chemical discovery by Lavoisier (the historical successor of Stahl as Stahl was the historical successor of Roger Bacon, and the consolidator of Positive Chemistry), and it led him right to the revival of the Newtonian application of the idea of Democritus. He discovered the fact of definite proportions in chemical combination and decomposition. Two brothers of the name of Wenzel had well-nigh anticipated the discovery by 1777, but only within a very small range of inquiry. In 1792 Richter had pursued their conception a little farther, and published tables of the combining ratios of certain acids and bases. But Dalton generalised the indication in all its breadth, and rose to its dependence on the Atomic Theory of sensible forms. Wollaston and the late erudite and independent Thomson of Glasgow College were his earliest converts of established reputation. These ingenuous men, followed by Davy, Gay Lussac, and Berzelius, and by the whole phalanx of the chemists of the present century, quickly carried the fact of chemical proportionals, as associated with the idea of the homœomeric constitution of matter, towards its consummation through a million of new and interesting particulars, and not a few important general deductions ; and now the ancient theory

stands embodied in the entire fabric of an absolutely post-Christian and most practical science. Dalton began to promulgate his views towards the close of the first decade of the century : they were conceived and crescent by the beginning of it : the new system was published in 1808-10. Some twenty long years after that historical publication, Daubeny, the Oxford professor, rendered its fontal thought familiar to the English student. Turner explained it in a shorter and more popular essay. Berzelius's large Treatise, and all the minor text-books, up to the latest manual of Organic Chemistry, are so many elaborate illustrations of the fact of chemical proportionals, and of the Atomic Theory of Democritus, Newton, and our Dalton,—the Manchester schoolmaster, and the greatest discoverer of the times in which he lived.

Now that it has been worked out by its originator and his exact and scrupulous disciples—to a wonderful degree, that is to say, but not nearly to completion—the Atomic Theory of the nineteenth hundred years of Christianity is characterised and distinguished from that which preceded our era, by three notable things ; but first and foremost by one glorious peculiarity : and the glory is of a right Christian kind, being no other than the grace of humility. It does not overween ; it does not dictate itself ; it is not oracular. It comes forward, knowing that it is a hypothesis. It offers itself as a sufficing explanation of all known phenomena at all related to its idea. It claims no divine rights as a revelation of genius, nor professes to be demonstrable after the manner of a geometrical or logical truth. It simply advances as an exceedingly probable proposition, willing to rest its reception as such on the amazing number and the significant kind of things it renders coherent and

intelligible. Like the theory of celestial gravitation, it is its simple and self-possessed plea that it explains everything. Its more arduous advocates, indeed, are not slow to avow their conviction that the mass of such presumptive evidence in its favour is so mountainous and transcending as to constitute an analogon of demonstration so compulsive, that only the unreasonable and as it were imponderable mind of an ignorant person or a fool can resist its force. This may be very true, for anything we know to the contrary; but the wise and positive chemist will always consider and adduce the Atomic Theory as a venerable and marvellous hypothesis, indefinitely likely to be the very truth of nature, but neither recognisable as such by sense, nor demonstrable by reason, yet conceived, defined, tended, cherished, and continually eyed with hope, not only as the all-sufficient rationale of his young though gigantic science, but also as the organ of advancing discovery. As for the idea of it, he will frankly confess that it is none of ours; it came down upon us from the oracular schools of Greece; but, as for its application to the present and practical affairs of the laboratory, he will use it as not abusing it, being bent upon the excavation of new particulars, more than on the contemplation of old and even everlasting universals. At all events, whatever be his living thought as a man, such is bound to be his formal judgment and sentence as a methodologist, or professor and practitioner of the logic of chemistry. The man of investigation must be as wary in his walk and conversation as a woman, in their several worlds: neither honest impulse and intention, nor yet the poetic license of eloquence and love, will suffice; the very appearance of evil must be shunned, because sinister appearances argue sinister causes of some sort, as surely as the shadow brings its substance.

A quick glance at the kinds of phenomena rendered intelligible, that is, truly conceivable by this theory, will illustrate these remarks with sufficient enlargement. They are three. There are, **FIRST**, all those common phenomena of the immediate sensible forms of matter which are ordinarily distinguished as being mechanical in contradistinction to such as are chemical or vital ; but since astronomical movements are quite mechanical, the phenomena in question had better be called somatic. They are those material movements and alterations which are produced by the repulsions and attractions of cohesion, as chemical mutations are produced by those of affinity, as astronomical evolutions are produced by those of gravitation, and so forth. This class includes the obvious natural changes and motions which have been signalised above as constituting the whole little material basis of the ancient Atomic Theory: the old and the new theories have that small segment of sensuous experience in common. The same facts, however, have received much elaboration in later times, under the influence of the experimental habit ; and many analogous things have been added to them. For example, it is now known that a gas may be contracted by cold to the liquid state, a liquid to the solid state ; and that the process may be reversed. Sulphuretted hydrogen is crushed in frigid strong tubes into a yellow liquor ; fixed air is compressed into a snowball, and tossed from glove to glove in our lecture-rooms ; solid zinc is melted, changed into dry steam or gaseous metal, and distilled like any alchemical spirit ; and so forth. Seeing it is the idea of such things, however, and not the details, that is now wanted, it is needless to particularise to any extent, under either this or the other two heads of illustration. Suffice it that the atomic hypothesis renders

all those somatic transitions conceivable, that is to say, intelligible according to the law of the human understanding. A solid can be crushed by cold or compression into smaller dimensions: it is, by hypothesis, because it is made up of small equal and similar particles, not in mutual contact, and therefore capable of being thrust nearer one another, so as to diminish the bulk of their aggregate mass. The same solid expands when heated;—its constituent particles being thereby driven farther asunder. The reader will generalise the application all over the ground for himself, taking in every circumstance of somatic commutation that he knows. The application is always easy, happy, unexceptionable; and, if the atomic view be rejected, there not only remains no better explanation, but absolutely none at all. In that case, the flowings, runnings, springings, enlargings, divisions, accumulations, and all the sensible interchanges of the face of nature, become a series of opaque and ultimate facts. Yet the scientific judgment must not be seduced by this temptation to accept the hypothesis otherwise than conditionally. Better no explanation for a thousand years to come, or even for ever and ever, than a wrong one: for no truth at all, so it be felt (like the Egyptian darkness) is less injurious than an error; and if brute ignorance is the fulsome parent of superstition, it is also true that conscious human Ignorance is the modest mother of Knowledge.

The SECOND order of things, brought into intellectual cohesion and harmony by our antique, yet most modern theory, belong to the region of astronomy. They are one or two mechanical phenomena on the grand celestial scale. Wollaston has proved, by certain optical phenomena connected with the invisibility of the fourth

satellite of Jupiter when out of sight by position, that the terrestrial atmosphere is limited in extent. It ceases at a short distance from the surface. It does not reach higher than 45 to 50 miles: beyond that there is a vacuum, so far as air is concerned. Yet air is, *in statu quo* at least, a self-expansive body. Remove pressure from it, and it swells to any bulk. Put an inch of air into a vacuum of a thousand inches space, and it straightway puffs itself out so as to fill the vacuum. Hence the atmosphere grows thinner and thinner the farther from the earth, owing to the diminishing power of gravity, that is to say, owing to the diminishing pressure on it. Yet it does not extenuate and rise any higher than 50 miles. Why does it not go on thinning, and ascending, and self-expanding? Why, according to this hypothesis, it is because the atmosphere is composed of mutually repulsive particles, the force of that mutual repulsion being a very finite thing, else the hand of a boy could not squeeze a quart of it into a pint-measure, as it can do with ease. The more expanded it is, the temperature remaining the same, the more easily is it compressed; that is to say, the mutual repulsion of its particles diminishes with their distance from one another. Hence the atmosphere ceases to swell—that is, to rise further from the earth's surface—just when the progressively diminishing mutual repulsion of its constituent particles becomes precisely so enfeebled as to be balanced and counteracted by the down-draught of gravitation. The solution is explicit, if nothing more. The limitation of the terrestrial atmosphere, it should be added, was pleaded by Wollaston also on the fact, that the observed and the real position of Venus when only forty-five hours from the sun, as observed by Kater and himself in May 1820, were identical,—proving that our

atmosphere did not extend to those heavenly bodies, else its refractive power would have disturbed the visible position of the planet. But the argument (or fact explained) is one and indivisible; and must be taken for what it is worth. It is at all events one notable and striking new fact contributed to the original stock of Democritus. Both this and the first of our three classes of phenomena, now being represented as craving and deriving explanation from the atomic hypothesis, are identical *in kind* with those scanty and obvious appearances, known to all men in a manner, on which the Greek physiologists erected their idea. They are only greater in extent and precision—thanks to the sacred experimental rage of Christendom.

But our THIRD class had no kindred in the old world. It is altogether modern, because altogether the result of humble toil. It is experimental; and that in the most elaborate and perfect degree, being experimental and numerical. It is the whole body of that vast, and altogether experimental, and literally hair-splitting science of Roger Bacon, Stahl, Lavoisier, Dalton, and Berzelius. After long and painful centuries of continuous effort, chemistry has discovered that the elements combine with one another in definite and unchanging ratios of quantity; and that, when their compounds are decomposed, they yield up those identical ratios. Everything is accomplished by weight, measure, and number: and that with pure geometrical accuracy,—could our instruments and senses but attain to perfection. Glauber's salt never yields other than one proportion of sulphuric acid, and one of soda; else, *ipso facto*, it is not Glauber's Sel Mirabile at all: and that one definite proportion of acid, that one of base, attend them respectively in all their combinations, as inseparably as a shadow tracks its

substance, or the moon goes with the earth. Water is always composed of 1 weight of hydrogen, and 8 weights of oxygen. When they combine in another proportion, it is in that of 1 to 16 or twice 8, and the product is no more water than aquafortis is laughing gas: it is a pungent new liquor, the deutoxide of hydrogen. Fourteen parts by weight of nitrogen combine with eight parts (the water-ratio) of oxygen, and the product is a sweetish intoxicating gas; nitrogen 14 with oxygen 16, or two ratios, produce the second oxide of nitrogen, a perilous air to inhale; nitrogen 14 and oxygen 24, or three ratios, compose the hyponitrous acid; nitrogen 14 and oxygen 32, or four ratios, are the ingredients of nitrous acid; 14 and 40, or five ratios, produce nitric acid: and these five compounds, made of the same elements in such differing proportions, constitute a series of substances, so well marked and contradistinguished that no mortal sagacity could ever have conjectured them to contain the same or even similar ingredients. What is the meaning of this series of 8, 16, 24, 32, 40, in the case of oxygen, whether combined with hydrogen or with nitrogen? Why, according to the Atomic Hypothesis of Democritus, as connected with the conception of affinity by Newton, and as united to that of number by Dalton, it is not the mass, but the constituent particles of oxygen that enter into chemical combination; and that with the particles, not the masses, of hydrogen and nitrogen respectively. Water is a compound (let it be said provisionally) of 1 atom of hydrogenous matter with 1 of oxygenous; while the pungent deutoxide contains, every compound particle of it, 1 atom of hydrogen and 2 of oxygen. Again: the laughing gas of Davy contains, every compound particle of it, 1 atom of oxygen; the binoxide of nitrogen 2 atoms of the same; the hypo-

nitrous acid 3 atoms ; nitrous acid 4 ; and nitric acid 5. Hydrogen particles being subsumed as unity for the sake of comparison, an oxygen atom is 8 times, a nitrogen 14 times, heavier than a hydrogenous one. In this sort of way, the combining equivalents of all the elements have been determined with a world of labour ; and, with the help of these, also those of whole hecatoi of compound bodies, acids, bases, salts, radicals, and all sorts of proximate principles. Waiving all particular questions—such as the inquiry whether 14 stands for one or for two particles of nitrogen, and suchlike points, probably more numerous and urgent than is commonly supposed—the uninitiated or reminiscient reader must conjure before him not hundreds, but thousands of such numerical series, and millions more of isolated facts of the same tendency, as well as add the later but corollary discovery, that the gases combine in definite volumes, before he can approximate to a due sense of the huge amount of presumptive evidence in favour of the theory under discussion afforded by Positive Chemistry. Yet that theory is only a hypothesis or ideal conception, placed by the mind like another Atlas underneath a measureless world of facts, to give them intelligible cohesion and hold them up to view. Without it, the fact of all chemical combination transpiring in definite and unchangeable proportions remains intact, and still invaluable ; but it is ultimate and opaque.—But Terminus, the old god of proportion, is as inexorable as the new laws of Dalton and Berzelius ; and it must suffice, for the present, to do no more than succinctly state the other two qualities which institute a broad distinction between the Greek and the Teutonic presentations of the Atomic Doctrine.

I. The enormous breadth of material or sensuous foundation, on which the latter has been being slowly

reared—from the pseudo-Christian polypharmacists of the East, till these the days of John Dalton the Friend, Baron Berzelius the Lutheran, and Faraday the Sandemanian—offers a wondrous contrast to the handful of stones gathered together on the highway, from which the former rose like an exhalation, or rather on which it condescended like a thing come down from Olympus or the Emyrean. This has been sufficiently set forth in the enumeration just made, of the kinds of phenomena which the hypothesis now offers to explain, without forgetting its place or station, as nothing more than hypothetical, in the system of positive thought.

II. The only other differential characteristic of the modern aspect of this time-honoured theory, to be noticed in the present connexion, is its availableness—a working chemist might well say its gracious obtrusiveness—as an organ of new and nobler researches. It does not any longer dwell on high; it expatiates over the islands and wide continents of nature. Its ideal existence is no longer a kind of endless now; it lives and seeks congenial food from day to day. “To-morrow to fresh fields and pastures new!” For example, the fact of isomerism, or the known existence of two (in some cases of many) totally different substances being composed of the same elements in the self-same proportions, is truly confounding and hopeless without it; but with it, there is no difficulty in the matter. Our solar system were another unit than it is, if the planets were differently distributed;—if our earth, say, changed places with Jupiter, Mercury with Mars, Saturn with Neptune, Saturn’s rings with Jupiter’s satellites, and so forth. And in like manner a compound particle, changing the relative placings of its constituent atoms, becomes thereby another particle altogether, giving rise to a new sensible

form isomeric with the former one, inasmuch as it still comprises the same elemental atoms in the same proportion, but differently arranged within its complicated round. Other isomeric pairs (not to go beyond a pair) are to be explained by the second or denser members containing exactly twice or thrice the number of the same kinds of atoms as the first, within the girths of their respective particles. Thence there is suggested the two startling ideas, that the former schematism may one day unriddle the mutual relation subsisting between such pairs of the hitherto intact elements as are represented by the same atomic weight, such as platinum and iridium; and that the latter may lead to still richer results in the same direction. Moreover, our hypothesis is big with hints of experiment upon the weights, sizes, distances, gyrations, evolutions, involutions, and resultants of those orbicles of matter which are its proper subjects. It renders the application of geometry and the calculus to these invisible, but computable stars in little, a thing of hope. Organic chemistry, which is now nought as a chemistry of the living plant and animal, though most important as a chemistry of the dead, cannot be wrought out from amid the phenomena of vitality until many, if not all these questions, and more, be brought to judgment; for it is impossible to separate between the chemical and the vital, before the idea of what is chemical and what not be determined by exhaustion.—But we must refrain. Perhaps enough has been said to suggest more.

In conclusion: still the inquiry recurs, how the aboriginal idea or fundamental conception of this beautiful, hundred-eyed, and hundred-handed theory came into the world; that idea, which it might never have entered

into our heart to conceive ; and which was, in indisputable fact, derived to us from a Hellenic and pre-Christian School. Was it by such revelation as is claimed for the profound ideas of Holy Writ ? Was it by that inspiration which all men are fain to accord to Homer ; Dante, Shakspeare ; to Praxiteles, Raphael, Turner ; to old Bach, Handel, and Beethoven ? Certainly not by anything like the former : and if by aught resembling the latter, that must be better defined before it will throw any light on either its own or any other subject. The process was as follows, in our humble opinion. The Grecian intellect had an unprecedented and still unequalled keenness of eye for the analogies of things. The slightest resemblance caught, charmed, and fixed its glance. The analogy of the Milky Way doubtless carried the swift imagination of Democritus to the conception of a star-like constitution for the sensible forms of nature. The Atomic Theory is just the fact of the unitary world of stars come down, and imaged in a dew-drop, or taking a sand-grain for its orrery. It is this analogy, in truth, which at once constitutes its clearness and perfection as a thought, and legitimatises it in the presence of a positive methodology. But the earlier Greek sages were not positivists, whatever may have to be claimed for Aristotle. They rather believed in their sense of analogies without more ado. They knelt before the ideal creatures of their imagination. Beauty and fitness were enough to command their faith, so they were of the intellectual species of beautiful propriety. It was their proper genius to see analogies with telescopic vision, while yet a great way off, and to believe in their own conception of what they saw : for the moral attitude of the Greek populace (to speak of men as belonging to the thinking, not the social

scale) was that of vanity—of the philosophers, that of pride, intellectual pride : and no wonder ; for they were a marvellous people, and their sages the most intellectual men the world has yet been able to produce.

Christ, Christianity, and the Christian era (surely about to be fairly inaugurated in some degree of purity ere long—*Usquoque Domine !*) present an aspect the reverse of all this magnificent self-exaltation ; that is to say, in their real character ; and their true nature has always been shaping men more or less, directly or indirectly, especially our greatest men. Now self-distrust, humility, obedience, faith in One who is mighty to bless, awe before the creation of the Word, the way of pain and sorrow, are the order of the new-born day that sprang in Bethlehem of Judah. It is now obedience that makes men free. If they would enter into the Kingdom of Heaven, they must come as little children ; and Francis Bacon has finely said, the kingdom of Nature admits no other guests. Fact, the actual thing in Nature, the very text and letter of that great and public manuscript of God, are now sacred once for all ; and no pains dare be spared in their study. This is the moral clue to the new, most patient, self-distrustful, yet always well-rewarded science of Christendom. There is also an intellectual key to its peculiar nature and destination, furnished by the intellectual character of Christianity ; and, indeed, certain secondary lights might be thrown on the subject by the consideration of race, climate, and such minor elements : but these closing remarks, taken together with the hints of thought scattered in the course of the discussion, are sufficient to illustrate the cardinal proposition of the present Essay.

II.

ALCHEMY AND THE ALCHEMISTS.

IN the case of a purely modern science, like geology or statistics, there can be little dispute and no mystery about its origin and progress. It is analogous to the United States of America. Its history lies, first and last, under the eye of present daylight: hour after hour recorded by the press, that chronometer of recent ages. Such sciences as astrology and alchemy, on the other hand, ran their courses in the twilight of time, having taken rise in the starlit night of history. Resembling the nations of antiquity in these respects, they resemble them also in tracing their origin to giants, prophets, superhuman heroes or demigods. This fabulous character of the early annals of those dark-age mysteries—for they were schemes of esoteric dogma rather than explicit fabrics of knowledge—is the first thing that attracts the attention of the historical student of alchemy.

The very etymology of the word is lost in hopeless obscurity. Scaliger says he saw a work in the king of France's library, written in Greek, by Zozimus the Panapolite, in the fifth century; and Olaus Borrichius seems to intimate that he also had read it, although it is in a somewhat ambiguous passage that the hint occurs. They represent it as 'a faithful description of

the sacred and divine art of making gold and silver.' Borrichius gives what professes to be an extract from it, in which the writer first refers to a fact which he had managed to deduce from the Scriptures, Hermes Trismegistus, and many other sources—namely, that there is a tribe of genii possessed of an unhappy propensity to fall in love with women. 'The ancient and divine Scriptures inform us,' he gravely assures the worthy Olaus, the learned Scaliger, and others his readers, 'that the angels, captivated by women, taught them all the operations of nature. Offence being taken at this, they remained out of heaven because they had taught mankind all manner of evil, and things which could not be advantageous to their souls. The Scriptures inform us that the giants sprang from these embraces. Chema is the first of the traditions respecting these arts. The book itself is called Chema; hence the art is called Chemia.'

Even supposing for a moment that the preamble of this singular account is true, and that the 'Sons of God' did impart many a primitive secret to the 'daughters of men,' it is not easy to perceive how a tradition could also be a book; and there would remain for explanation the name of the book itself. Plutarch, however, asserts that Egypt was sometimes called Chemia, and Panapolis was an Egyptian city. It was, moreover, another of the favourite opinions among the Arabian as well as the earlier European alchemists (an opinion entertained by Albertus Magnus amongst others) that Hermes Trismegistus was the father of their science. That august personage is represented as having flourished two thousand years before the appearance of Christ. According to Kriegsmann, Avicenna and other Arabian polypharmists believed that Sarah took a table made of

zatadi, supposed to have been emeralds, from the hands of Hermes, entombed in a cave near Hebron. On this table were inscribed the dogmas of the master concerning his chemical secrets, in thirteen mysterious sentences. In the twelfth of these enunciations, he informs the discerning public that on him 'was imposed the name of Hermes Trismegistus, because he was the ordained doctor of three parts of the wisdom of the world.' Now, although the very name of this supposed interpreter, not to speak of still more obvious internal evidences, is quite sufficient to prove the purely mythical character of the whole story, the existence of this tradition among both the eastern and the western adepts seems to render it not unlikely that the etymology of the word is connected with Egypt. Borrichius's own private opinion is clearly to the effect, that the hermetic art descended from Tubal-Cain or Vulcan ; but he allows that there is much to be said in favour of Trismegistus, who has been supposed by some to have been Chanaan, the son of Ham, whose son Mizraim first occupied Egypt.

It has to be mentioned, in fact, that the word Thoth, the Egyptian name for Hermes Trismegistus, means a pillar according to Josephus and Manetho ; in which, it seems, they are corroborated by Jablonski. The truth of the matter appears to be, that pillars were early used by the Egyptians for the same purposes as parchment and paper have been employed by the literary men of more modern nations. These pillars were their books and standard body of literature. It farther appears that there were three successive Thothes or schemes of inscription ; that is to say, three dispensations or epochs of pillared literature. The first set are said to have reached down to the time of the Flood ; the second contained all that was discovered or thought during the infancy of

the scientific knowledge of these ancient people ; and the third was the embodiment or publication of the full-grown science of Egypt. Hence the whole system of pillars was readily impersonated under the mythical appellation of Hermes Trismegistus, the thrice-great interpreter, as the name implies. It is, accordingly, easy to understand how that illustrious and encyclopedical author was subsequently represented as having composed thirty thousand volumes ! It must be confessed that all this looks very satisfactory, not only as explaining the traditionary story of Trismegistus, but also as confirmatory of the historic hint that the word 'chemistry' is of Egyptian origin, as has already been shown to be not unlikely.

On the other hand, it has been customary among more recent critics than these mediæval speculators, to make the root of 'alchemy' a Greek word. It has been supposed to be derived from *χυμη*, which signifies *juice* or *menstruum* ; and to refer to the acids, leys, and other solvents in use among chemists and alchemists. This was the favourite etymology among the very latest of the European adepts ; and it gave rise to the spelling of the word with *y*—*alchymy*. Boerhaave contended that it was drawn from the Greek word meaning *to fuse* or *melt*, *χέω* ; and ever since the inculcation of this etymology, both *alchemy* and *chemistry* have been written as they are printed here, in deference to established custom. Webster resists this derivation ; spells them *alchemy* and *chimistry* ; and remarks upon the noticeable circumstance, that the southern nations of Europe have never yielded to the Teutonic innovation.

It is unfortunate for these specimens of Græco-mania, that neither the word *chemia* (*χημεία*), nor any etymon connected with the notion of *alchemy* or *chemistry*,

occurs in any Greek author before Suidas, who is said to have produced his Lexicon in the eleventh century, under the Emperor Alexander Comnenus. That lexicographer explains *chemia* to be the conversion of silver and gold ; and is of opinion that the art of doing so was known to the Egyptians in the time of Diocletian, who is said to have burned all the manuscripts in Egypt, in order to put an end to the pursuit. Suidas also suggests, under another head (*Δέπας*, a skin), that the invaluable fleece, which Jason and his argonauts carried off from Colchis along with Medea, was nothing less than a treatise on gold-making written on hides. This is of course a piece of private and personal ingenuity on the part of Suidas ; and, as such, it is not unlike another esoteric doctrine which some one has fetched us from the East, to the effect that the 'Arabian Nights' is a symbolic setting forth of Alchemy ! In fine, there seems to be not the shadow of a reason for surmising that the ancient Greeks ever dreamed of the matter. They had neither the name nor the thing.

In whatever way this significant question concerning the origin of the substantive root of the word be eventually settled, there can be no dispute about the prefix. The unquestionably Arabic character of that particle, indeed, appears to indicate the fact, that al-chemy, as such, had its historical, though, probably enough, not its traditional origin in Arabia. Johannes Chrysippus Fanianus, or an author under that somewhat too significant name (for there is no department of literature so overcrowded with spurious productions as that of the Spagyric art), is careful to insist that the polypharmists meant more than is apparent in denominating the doctrine of transmutation *the chemia*. According to him, they recognised a difference between all common chemi-

cal operations and the 'great projection.' Such operations belonged to the domain of vulgar chemistry, but transmutation was represented as being dependent on more secret and interior principles. It was the chemistry of chemistries, or alchemy.

There has been implied in these observations on the derivation of alchemy a certain degree of discussion of the origin of the science itself. It is needless to inquire into the tradition, for example, which traces it to Moses, whose empirical knowledge of metallic reactions must have been not only considerable, but almost beyond that of the present day, if the Hebrew word be correctly translated in the account of Aaron's golden calf, given in the book of Exodus. It is said that the Jewish leader and legislator burned the idol, strewed the ashes of it upon the waters, and embittered the drink of his impatient host. Now it has been remarked that, in order to produce such effects upon gold, he must have been, at least practically, acquainted with the properties of the sulphur salts—a class of compounds which have been discovered by the modern experimentalist only in very recent times. It is impossible, however, to come to anything like a satisfactory conclusion on such a point, after men like Spinoza and Fabre d'Olivet have united with the rabbinical school of these ages in asserting that the Old Testament is far from being properly rendered, even in the Septuagint, in a multitude of particulars. It is, indeed, almost universally allowed, even amongst the most bibliolatrous of Protestant interpreters, that the glory of our version resides in its conveyance of the spirit of the Sacred Writings, and not in its literal fidelity concerning every petty detail. There can be no manner of doubt, for instance, that the word translated *nitre* ought to have been expressed by *natron*

—that is, soda, or, more strictly speaking, the carbonate of soda. Hence Solomon illustrates one of his sharpest proverbs by the action of ‘vinegar upon nitre,’ referring to the violent commotion and effervescence which ensues on the mingling of natron and that acid; the principle, in fact, upon which the effervescing draughts of the modern apothecary are prepared. It is not altogether improbable, therefore, that the gold of Aaron and his rebellious brethren may have been a kind of brass or pinchbeck, with a large proportion of gold—a supposition which would render its calcination quite intelligible, without assigning anything like remarkable chemical information to the indignant prophet. Howsoever all this may really be, moreover, it is not to be overlooked that the practical acquaintance with even very complicated processes of this sort does by no means imply a scientific knowledge or rationale of chemistry. The arts of baking and brewing, for instance, are dependent on very complicated and recondite principles of action and reaction; yet it is generally understood that they were found out by ‘rule of thumb,’ and not discovered by induction.

Accordingly, one is prepared to find a positive and methodical chemist like Dumas setting all those antique claims imperiously aside; putting that of Maria the Jewess, a kind of mythological Joan of Arc in this fantastical region of fabulous history, among the rest. ‘We can no longer,’ says that eloquent philosopher, ‘place the cradle of chemistry exclusively even in the laboratory of the ancient pharmacopolists, to whom some are willing to attribute its discovery. The services we have done raise us quite high enough to enable us to remember, and that without embarrassment, our obscure parentage. Let us confess at once, then, without going

round about it, that practical chemistry took its rise in the workshops of the smith, the potter, or the glass-blower, and in the shop of the perfumer ; and let us just agree that the first elements of scientific chemistry date no farther back than yesterday.'

Although this judgment seems to be very sensible and very natural, as coming from so great an ornament of the present school of chemistry, neither the one nor the other of the terms of which it is composed can stand the scrutiny of a stricter dialectics. In the first place, practical chemistry is not practical chemistry until it has first been theoretical or doctrinal chemistry. The moment an inventor bethought himself of using some chemical discovery or other for the purpose of economical art, the idea of practical chemistry was conceived. The origin of practical chemistry must therefore have been posterior to, or, at the earliest, coincident with, that of theoretical chemistry, be the date of the latter what it may. If, however, this criticism appear to be nothing better than a verbal or logical refinement, there is another consideration which is as unobjectionable as it is obvious. Accepting any less precise definition of practical chemistry than has just been given, why stop at the workshops of civilised, or even of semi-civilised life, in tracing it to its rise ? Why not ascend at once to Adam and his primeval family ? If practical chemistry consist in the performance of operations which are essentially chemical in their nature, then the first man who kindled a fire, roasted an ox, or seethed a kid, was the father of all such as deal in that manifold art. These observations are certainly very unimportant, but so is the question which they concern ; and they are offered for no other purpose than to prepare for the serious discussion of Dumas's second opinion about the history of

chemistry. He asks us to grant that the first elements of scientific chemistry date no farther back than yesterday. It is the common opinion among the chemists of to-day. They are for the most part so dazzled by the really brilliant results of very modern chemistry, and so blind to the possibility of any of its first principles being only temporary and remote approximations to the truth, as to be incapable of tracing the theory of chemistry any farther back than the memorable days of Lavoisier, in the light of whose thought they still rejoice and work. Without caring to protest against this amiable idol-worship of the immortal Lavoisier, we deny that doctrinal or scientific chemistry is the contemporary of either the printing-press or any other modern instrument, whether of thought or of handiwork.

The Lavoisierian chemistry was only one of the epochs of the life of the science. But there were epochal developments before that of Lavoisier, just as the Daltonian era has come after it. Each of these movements had not only its grand and abiding truth to bring forward, but also some important and deciduous error to leave behind it, as might easily be shown to have been the case with the French chemistry itself. In one word, alchemy (to say nothing of the post-alchemical doctrine of phlogiston at present) had its genuine scientific function to perform, and its distinct scientific value in the history of chemistry. A true history of the science, in fact, would exhibit one continuous stream of truth mingled with error, from the origin of alchemy down to the latest discoveries and views. In the meantime, we shall unfold the story of the early progress of chemistry, with the aid of the competent authorities; and in doing so, we shall find a sufficient deliverance of all that is necessary, in the present connexion, concerning the alchemists; and concerning

their relation to science in general, as well as to chemistry in particular. It is desirable, however, to take a preliminary glance at the ideas of classical Greece respecting the theory of nature, for it will be found that those ideas have had not a little to do not only with alchemy in all its stages of evolution, but also with the chemistry of Dalton and the future.

Nor will the reader grudge the time and the labour of thought bestowed on such distant topics, when he finds that the consideration of them is fraught with lessons of importance. He will learn that man never labours in vain when he is sincere, devout, and industrious in his endeavours, as the alchemists will be discovered to have been. He will perceive to his delight, moreover, that there is no such thing as revolution in the progress of science, but only the large and solemn growth of a living creature. Nor will it be difficult to extend such precious verities from this, their private and particular sphere, into the grander domain of universal history.

It was Thales of Miletus, the father of Greek philosophy, who methodically originated the conception that *water* is the first principle of things. He inculcated the scientific dogma that water is the one substantial or underlying essence, of which the rest of nature is but the manifold expression. Water was represented in his system as the sole and primeval matter, convertible and actually converted, by some plastic power, into the thousand-and-one familiar creatures in the universe: now into this one, and now into that; now into wood, and now into stone; now into the grass of the fields, and now into the body of man himself. Nor does this doctrine appear to be fantastical, as has been remarked by Ritter, when one reflects how rocks and salts can be extracted by mere boiling and evaporation, not only out

of the sea, but also from the most insipid of lakes and streams, and even from rain. It is not yet beyond the memory of man, that Lavoisier was careful to distil water backwards and forwards in an alembic for many long days and nights together, in order to settle the question whether water were actually convertible into earthy matter, as had been asserted and believed by his immediate predecessors. Scheele, one of his most distinguished contemporaries, instituted another sort of experiment upon water, with a view to the determination of the very same point. It is not fifty years since Davy conducted his celebrated experiments on the electrolysis of water by means of the galvanic current, with very much the same object in view. It is, accordingly, easy to perceive that the ceaseless circulation of the liquid element from the ocean into the air, and through the air again to the earth, in dews and mists and rains, only to run once more from springs and streams and lakes and rivers, down to the ocean whence it rose, must have impressed the youthful science of ancient and imaginative times with the supreme importance of water in the economy of creation. But this contemplation of nature as one vast alembic, for the revolution of that beautiful and lifelike creature, was not the only motive to its exaltation as the best and first of things in the mind of Thales. The marvellous effects of moisture in its varying forms of river, rain, and dew, in covering the hills, the valleys, and the plains with verdure, during the flushing spring of Asia Minor and the Archipelago, to say nothing of the indispensable necessity of water not only to vegetation, but also to animal vitality itself, must have gone deeper still into the thoughts of those venerable seers who were first visited by the inquisitive spirit of wonder.

Willing to forget the moon and all sublunary science, we have stood beside the sea a whole year round, and abandoned ourselves to its first impressions in the spirit of antique faith and awe. It moved for ever at our feet, now driving us before it, and then drawing us after it, its everlasting voices in our ear. One day it murmured about our steps, kissing the brown earth, and kissing it again, never weary of kissing the softened beach ; another, it was testy as a great wayward child, and chid the world the livelong day ; on a third, it was as angry as a brawling woman, and chafed along the shore ; another time it panted and heaved and lashed, like a hundred orators arousing the nations with their ire. Anon it swelled and roared, like an assailing host or an infuriated people ; and again it thundered responsive to the heavens, flashing back flash for flash, reflecting an infernal blackness upon the chaos of the falling sky. Its varieties of expression were as many as the days of the year, and far more ; but always it was moved from its very inmost, and always it moved to the impulse that stirred it, whatever that might be. It never lay still ; it could not be at rest ; it could not get away from itself. In vain it threw up spray and vapour and clouds ; they returned to its unresting bosom through unerring channels. They went and they came as surely as it ebbed and flowed. They and it were always one, and all nature was penetrated by the unity. Wherever it touched, living things sprang into being : plants, animals, and man ; only to be resolved again into the mighty organism of the waters when their lives were done. The ocean, reaching down to Hades, and stretching beyond the clouds, was the very blood of nature—"the blood which is the life." Blind to sun, moon, and stars, insensible to the firm earth on which we stood, and deaf to the solicitation of the air and all

its winds, we were lost in the contemplation of what seemed more alive than they ; and then we understood how the first-born of the Wise Men of old pronounced the great deep to be at once the womb and the grave, the beginning and the end, of all created things !

Nor is it difficult to comprehend how Anaximenes, one of the earliest of the successors of Thales in what has been called the physiological school of Greek philosophy, should modify the doctrine of his predecessor, and assign the foremost place in the theory of nature to *air*. The ingenious reader will easily place himself in this new point of view, with the help of that imaginative sympathy which has just been extended to the earlier tenet. It is to be particularly noticed, however, that air was not the same kind of thing to those primitive doctrinaires as it is to us. Thales and Anaximenes, in fact, did not fix their eye upon the actual ocean and atmosphere so much as upon an abstract conception which they had formed for themselves of the interior essence of these elements. It must not be forgotten, that in the childhood of human thought, as in the childhood of the human individual, there is no unmistakable distinction yet drawn between the world of sensation and the world of consciousness. The external world is still little more than a wondrous procession of perceptions, thought as sensation not being yet differentiated in the mind from thought as knowledge. The universe is still a passing scheme of shows and shifting modes of the perceiving spirit. Thales and Anaximenes beheld the green tree, the blue sea, the brown earth ; and not, like Bacon and Locke, not merely a tree (or a somewhat) so propertied as to produce the image of a green tree in the mind, through means of the laws of light and the retina of the eye ; not merely an earth (or another somewhat) which

optics and physiology make into a brown earth ; not merely a sea uniting with the eye to produce a blue sea between them ; and so forth. In one word, those sagacious children of thought, the ancestors of Plato and Aristotle, were natural idealists ; they were born idealists, not knowing that they were so ; for they had never reached the point of scientific scepticism even for a moment.

Hence Anaximenes is represented as discoursing concerning air as the equivalent of intelligence or soul. It was his god—one, eternal, and unchangeable in essence ; so that he stood at no great distance from that ancient and public spirit of poetry which fashioned the languages of mankind. The grand difference, indeed, between Orpheus and Hesiod on the one hand, and the first teachers of philosophy on the other, consists in the circumstance, that the latter had developed for themselves and for all succeeding ages the idea of methodical investigation ; a fact which constitutes them the fathers of science, notwithstanding that their specific doctrines are now of little use. The conception of one aboriginal source of all visible things, common to the schemes of Anaximenes and Thales, is a scientific statement of the poetic myth which pictures Proteus as the solitary and god-begotten shepherd, eternally driving innumerable herds and flocks of all kinds of creatures before him. It is remarkable, in connexion with the Thalesian form of this idea, that all those subordinate deities which regulate the affairs of nature, are figured in the Orphic theogony as the children of Oceanus and Thetis ; Oceanus the monarch of the sea, and Thetis the ocean-bride ; Oceanus the male energy of essential water, and Thetis the female ; Oceanus the positive, and Thetis the negative forces, which constitute the visible unity of

that omnipresent radical moisture, from whose exhaustless bosom all other things proceed. It is impossible for the imagination of 1851 not to descry the subtle thread of thought which seems to associate this venerable pair, Oceanus and his Thetis, with the oxygen and hydrogen of our own chemistry ; especially when it is remembered that chemists so thoroughly accomplished as Davy and Prout have seen nothing repugnant to the genius of modern research in the conjecture that oxygen and hydrogen, the married coefficients of water, may prove to be the original elements of the whole world.

It may be mentioned, in passing, that in all the cosmogonical myths of the Greek mind there flickers the idea of polarity, the law of the inevitable dualism of things, the fact of the universal chemistry of nature : two in one, active and passive, positive and negative, male and female, and the unity of such mutually-conditioned pairs in this single creature and in that. We say 'the universal chemistry of nature ;' for it is the essential aim of chemistry to discover two constituents in every one thing : sulphuric acid and soda in the Wonderful Salt of Glauber ; sulphur and oxygen in sulphuric acid ; sodium and oxygen in soda ;—and what pairs in sodium, oxygen, and sulphur ? Nor is it necessary, in the present connexion, to do more than state the fact, that this very idea of the bipolar unity of all sensible phenomena, generalised to the utmost, is at once the deepest and the widest of the grand principles fairly established by the genius and industry of recent science.

Diogenes Laertius asserts that the illustrious doctrine of the *Four Elements*, with the unspent echo of which we have all been familiar since the Christmas-games of childhood, was first promulgated by Pythagoras ; one

of those gigantic spirits of antiquity whose personality history can scarcely catch a steady glimpse of, but whose shadow lies large and long upon the world of old. If this report be true, it is probable that the Quaternion was filched from Egypt; and that might be the ground of the tenacious conviction of the alchemists, that their mystery descended from that land of wonders and the Nile. It seems, however, to have been Empedocles who not only gained the dogma a footing in the world, but also elaborated it into a consistent hypothesis of nature. Empedocles, a man of condition, a legislator, a theologue, and a poet, belonged, as a philosopher, to the second movement of Grecian science. Thales and his schoolmen had attempted to solve the nature of the universe, including under that significant epithet the all-embracing unity which results from the three worlds of sensation, consciousness, and conscience turned into one; a comprehensive definition implied in the very word itself. They approached and contemplated that universe as one and divine: they aspired to the solution of absolute being. Heraclitus, Anaxagoras, Empedocles, and Democritus, on the other hand, were content to fly a lower pitch. They investigated the theory of nature, properly so called; and also, like Descartes and Bacon, the origin and methodology of science. If we had to discuss the great discoveries of Dalton and his compeers in chemistry, we should have occasion to adduce the atomic theory of Anaxagoras and Democritus; but at present it is only the doctrine of the Four Elements that falls in our way.

That famous dogma may be considered from two several points of view. It may be taken as a concrete proposition, or as an abstract one. It may be studied as a particular or as a general tenet. It has indeed been

presented under both these aspects, since the days of its origin down to the period of its adoption by Oken, a contemporary of our own. Viewed as a particular proposition, the theory of Empedocles was simply this:—A handful of wood, or of any other ordinary combustible, is kindled and burned upon the surface of some cool body: the experimentalist observes that, while it burns, there rises smoke or *air*; the smoke is followed by flame or *fire*; moisture or *water* is deposited on the settle, or any other cold substance in the way; and ash or *earth* remains. The wood has been resolved into its coefficients, factors, or elements; and these are four—fire, air, earth, and water. But the burning of wood had never been a scientific experiment before. It was not a chemical experiment, and from the very nature of the subject it could not become so, until such time as it was intentionally observed with a view to the determination of the composition of wood. A thunderbolt was not an electrical experiment until Franklin conceived of it as such, and varied it at will. An initiative idea must always accompany, if not precede, any natural phenomenon, in order to render that phenomenon an experiment or scientific observation. The intention, the observation, and the conclusion of Empedocles concerning the world-old process of combustion, then, constitute the first methodical or consciously scientific reflection ever made upon a chemical transformation. It is therefore nothing less than the long-sought origin of chemical science. For what is a science? It is the body of methodical or consciously scientific reflection on the observed phenomena of any one department of nature. Is it necessary to the nature of a science that it be all true, and that it contain no admixture of error? By no means: else chemistry was no science during the reign

of phlogiston ; optics no science during the predominance of the materialistic theory of light ; the Lavoisierian chemistry no science as long as oxygen was taken for the principle of acidity ; ay, and the chemistry of to-day might very easily be proved to be no science any more than the rest. We have put our finger on the very fountain-head of all succeeding chemistries at last.

The Greek mind, however, could never hold exclusively by the concrete. It did not delight in details : it hastened to generalise : it loved particular nature indeed, but it never rested until it had glorified the particulars of nature into types of the universal. Hence their sculpture, their drama, their philosophy ; and hence their want of a self-fulfilling science of nature like ours. Fire, air, earth, and water were not only chronicled as the constituents of wood or common combustibles, as they would have been had it been possible for Empedocles to have sat at the feet of either Roger or Francis Bacon ; they were at once canonised as the sufficient and indispensable components of the whole of nature. There was accordingly an end of chemistry proper among the Greeks at once and for ever. The first step nobly taken, they never took another. On the contrary, they soon refined upon the elements they had discovered. Demetrius of Abelæa fell back upon the Thalesian notion, that there is necessarily only one true and primitive substance ; and he represented the four elements of Empedocles as its visible representatives. Plato seems to have followed Demetrius in this conception to a certain extent, complicating it with speculations concerning the shapes of fire-atoms, air-atoms, and so forth ; and maintaining, on the strength of apparent observation, that fire, air, and water are transmutable into one another, but not earth. There therefore re-

mained only two permanent elements in the Platonic scheme. One of these was the common principle of fire, air, and water, mobile, penetrating and quickening ; the other, the earthy principle of things, was fixed, penetrable, and capable of being vivified. Plato, in fact, reduced the analysis of Empedocles to a shadowy doctrine of dualism. Aristotle, on the other hand, rejected the Platonic tenets concerning both ideas and matter, as well as the numerical idealism of Pythagoras. He held by the Demetrian idea of one underlying substance as the ground of all natural phenomena. He believed in the one radical matter of the universe, and argued that the four so-called elements are not such in reality, seeing they can be converted into one another. What subtleties and mysticism men are sometimes led into when they leave the path of observation ! But every nation has its function. It was that of Greece, in so far as knowledge is concerned, to furnish the rest of time with nothing more than clues to the arcana of nature. But it was still more emphatically the mission of the Greeks, as philosophers, to discover those laws of investigation according to which alone such threads could be followed into the labyrinths of creation with advantage. The great result of all their centuries of striving was accordingly the invention of the inductive method by Aristotle ; that mighty organon which, almost rediscovered, and certainly restated in a more practicable form by Bacon, has made us what we now undoubtedly are—the entering heirs of nature and all her inexhaustible wealth.

Such is the doctrine of the four elements. It has been domesticated with literature for more than two thousand years : it has been sung in the poetry of every land : it has been attacked, overthrown, and proscribed by modern science ; yet it has actually been revived in

our own days as the basis of the philosophy of nature ! There is only one thing more to be said of it, considered as a particular proposition. That primitive analysis of wood by Empedocles, viewed as a chemical experiment, was actually a good one so far as it went. Wood is in reality composed of fire, air, earth, and water. They are its proximate constituents in a manner. Only modern analysis has gone farther still : it has divided the phenomenon of fire into the phenomena of heat and light : it has found smoke to contain carbon, oxygen, and hydrogen, not to be too minute : it has resolved water into oxygen and hydrogen. The ash or earth has been decomposed into several other substances by its more relentless methods.

These four elements, however, were also regarded in a more abstract and classic light in the Grecian schools, as has already been observed and slightly exemplified. Each of them was a type ; each of them stood for a vast class of things. Air represented gasiformity ; water, liquidity ; earth, solidity ; and fire, the imponderable forces of nature. Fire, air, water, and earth were frequently used as the philosophical symbols of what we now denominate the imponderables, gases, liquids, and solids respectively. They became abstract terms, and were constantly losing their chemical or particular significance in the besetting tendency of the Hellenic mind to excessive abstraction. It is scarcely necessary to add that, in this abstract phraseology, three of the four elements are at length demonstrated to be actually convertible into one another. When a solid body is heated, it swells and swells until it falls down liquid. On the elevation of its temperature, the liquid swells in the same way, and is finally converted into a steam, dry gas, or air. The atmosphere we breathe is the steam of a

liquid or water, which boils at an incredibly low heat ; and that liquid is a melted solid. There is a temperature at which gold itself would be changed into a thin dry air, fit for the breath of some imaginable creature. The experiments of Faraday and Thilorier on the liquefaction and solidification of the gases warrant such conclusions. The relationship of those three generic forms of matter, in truth, is now understood to be unexceptionable and sure ; and the consideration of it casts not a little light on the prattle of Plato and Aristotle about the mutual convertibility of the elements. Nor will this twofold meaning of the doctrine of Empedocles be without its importance in the elaboration of a just conception of alchemy and the alchemists, as will soon be seen. In the meantime, we cannot proceed to that department of the subject in hand without quoting the opinion of Professor Necker of Berlin, as translated by Dr. Babington for the Sydenham Society. 'No mediæval author,' says he, 'omits an opportunity of representing conjunctions of the planets as among the general prognostics of great plagues ; nor can we, for our parts, regard the astrology of the middle ages as a mere offspring of imposition. It has not only, in common with all ideas which inspire and guide mankind, a high historical importance, entirely independent of its truth or error ; but there are also contained in it, as in alchemy, grand thoughts of antiquity which modern natural philosophy is so little ashamed of, that she claims them as her property.'

A good deal has already been said about the substantive root of the word 'alchemy,' and it has thereby been made apparent how little that is certain can be said about the matter. It seems that we must be content to accept it at the hand of one or other of the veiled

figures of antiquity, of whom we can see and say nothing. The reader has likewise glanced into the structure of certain doctrines concerning the theory of nature entertained by the Greeks. It has been found that Empedocles's canon of the four elements must be considered as the veritable origin of the science of chemistry, although the science was not known under any such name till many hundred years after the days of that early speculator. Chemistry, in fact, did not advance among the Greeks beyond its illustrious first experiment, and the broad but unwarrantable generalisation that was erected on it; a thing quite intelligible, when viewed in connexion with the intellectual proclivities of the national mind. There was a more urgent task before them than the working out of particular sciences; namely, the discovery and the exposition of the science of sciences—the science of method. Before they could invent sciences, they had to invent an intellectual organ, or conscious instrumentation, according to the laws of which the sciences were to be invented. Before discovering chemistry, they had to discover the art of discovering chemistry, to use a strong expression. Their progress in positive knowledge was accordingly small in extent, and great only in depth; while the successive schools, with or without a very distinct consciousness of what they were accomplishing, lavished all the energies of the most wonderful national intellect the world ever saw on the excogitation of the principles of discovery, the methodology of science, and the laws of thought. The consummation of the whole movement has been represented as having transpired in the person and the works of Aristotle; that is to say, its consummation in so far as the interests of physical, and indeed all positive science, were concerned. It would be more catholic to

say, the intellectual career of those schools found its apotheosis in Plato and Aristotle, viewed as the opposite terms of one result, and actually embodied as one, with some degree of development, in Socrates, their predecessor. Philosophy is the true Janus and keeper of peace. It has an eye for the earth, and an eye for the heavens : an eye for the sensuous, and all that arises from it by intellectual transformation and exaltation ; and an eye for the ideal, and all that descends therefrom upon the daily life of man : an eye for nature, and an eye for God. Aristotle was the perfection of the one, Plato of the other, of those philosophic functions ; and the union of these master-spirits in the person of one sage would make a complete philosopher, in so far as methodology could render him complete. Were, however, such an imaginary and perhaps impossible being to arise, as complete in mere panoply as Pallas when fresh from the brain of Jove, he would have to live and labour for ever and ever ere he should become a completed philosopher in the larger sense of the phrase ; for the sphere of objective truth is as unbounded as the empyrean. That is to say, there is only one complete philosopher—even the Spirit of Omniscience, of whom Plato has said it is perhaps better not to name Him, in case we should degrade His idea. As it is, Plato was the greater philosopher, for philosophy is primarily conversant with ideas ; and Aristotle was the greater man of science, for science has its dealings with the concrete in the first instance. To use a chemical figure of speech, less appropriate than in character, philosophy and the Platos of the world are occupied with the process of distillation by descent, whilst science and the Aristotles are engaged with that of sublimation. At the same time, Aristotle could not escape the habit of mind which distinguished

his countrymen—namely, an overweening tendency towards excessive abstraction ; and he philosophised upon science more than he invented sciences, amazing though the amount of his information and knowledge undoubtedly was. That is one of the reasons why the methodology of Aristotle, essentially practicable although it was, was so unproductive in the hands of his disciples. The methodology of science did nothing but degenerate after its great development in the philosophy of Aristotle, and that more especially in the department of physics. We have seen that, in so far as a possible chemistry was concerned, the prospect of anything like advancement was at once foreclosed by the vast over-generalisation made by Empedocles and his critics upon the analysis of common combustibles by fire. It was nearly the same in every other direction, always excepting those purely mechanical subjects which were susceptible of illustration by geometry. Unable to use the Organon invented for the use of thinkers by Aristotle—namely, that inductive philosophy which Lord Bacon has taught us the art of bringing to bear upon the castellated secrets of nature—they were content to make it the object of endless and unprofitable discussions. Unequal to the task of carrying out the intellectual life of Aristotle into the amplitudes of an external and a victorious development (as Locke, Newton, La Place and Lavoisier, Herschel and Dalton, have carried out that of Bacon), they were reduced to the alternative of setting him up as an infallible authority, the monarch of their thoughts, and the idol of their hearts. Long, too, did he reign, in spite of many an indignant protest by the masters in alchemy, as we shall find, until the final overthrow of the scholastic philosophy by Descartes and Bacon. Nor would the world have suffered greatly from this protracted domination, if it

had really been Aristotle that reigned. But it was not. It was Aristotle misunderstood and perverted. It was an Aristotle scarcely read, known only by transmission, and distorted by the vision of the schools. It was not the sun of Aristotle that these scholastics beheld and adored: it was only his zodiacal light. They did not study his great principles of investigation: they merely adopted his opinions regarding a host of special points; a thing which, done now-a-days to Bacon, would reduce him as low as ever Aristotle was degraded by his mistaken followers. The true Aristoteles, that best ending or greatest and last representative of the most illustrious line of royal thinkers this world has yet produced, remains intact. In reality, the methodologies of Aristotle and of Bacon are substantially the same. They are one method or doctrine of knowledge stated in two several ways. The Greek stated the inductive method subjectively; the Briton puts it objectively. The Greek developed it from within outwards, like the growth of palms; the Briton grows it from without inwards, like an oak. The Greek constructed the telescope, leaving it in the workshop of the mind where it was put together; and no man was strong enough to move it from the tressels, until the chancellor of Great Britain wheeled it to the air, and directed its resistless eye upon the heavens.

One has simply to understand, then, in the present connexion, that during those centuries in which alchemy shall be found to have been working in the mind of Europe, the dogma of the four elements, the vague idea of their mutual convertibility, and the supposition of some fifth element common to the four, or rather the very soul of all the four, were predominant among the learned. This, indeed, is one of the undeniable origins of alchemy; but there is another, for alchemy has two

historical sources : this one in old Europe, and another in Asia. The attention of the reader must now be directed to the latter.

It was during the caliphates of the Abassides, and apparently under their patronage, that the school of polypharmacy flourished in Arabia. The earliest work connected with that movement which is now known in Europe is the *Summa Perfectionis*, or 'Summit of Perfection,' composed by Geber. It is consequently the oldest veritable book on chemistry proper in the world, although it dates no farther back than the eighth century. Nor does the science derive much credit from this performance, when judged from one point of view ; for it contains so much of what sounds very like jargon in our ears, that, according to Dr. Johnson, the name of its compiler has been transmuted into gibberish for the use of indignant English tongues. Viewed under its legitimate aspect, however, it is a wonderful thing. It is a kind of textbook, or collection of all that was then and there known and believed for nobody knows how long back. It appears that those Arabian polypharmists had long been engaged in firing and boiling, dissolving and precipitating, subliming and coagulating, chemical substances. They worked with gold and mercury, arsenic and sulphur, salts and acids. They had, in short, become familiar with a goodly number of what we call chemicals in ordinary parlance ; although there is in reality no such thing as a chemical, for everything is one.

To these Arabians, however, chemistry was by no means a theory of all nature, considered under the chemical point of view, as it is to us. It was only the theory of a laboratory full of curious, rare, and aristocratical substances. Nor were they without their deep-reaching conjectures or dogmas respecting these strange things.

Geber taught the principle that there are three elemental chemicals—mercury, sulphur, and arsenic. The penetrating and victorious qualities of these bodies fascinated his thoughts. Even gold itself, which its weight, its beauty, and its incorruptibility by fire united to signalise as the most perfect of matters, is dissolved by quicksilver almost as easily as sugar is dissolved in water. Brimstone pierces iron like a spirit the moment they touch one another, if the metal be white-hot from the furnace; and they run down together in a shower of solid drops, a new and remarkable substance, possessed of properties belonging neither to iron nor to sulphur.

But they had their alchemical theory as well as this chemical one. They inculcated the proposition that all the metals are compounded bodies. This was a very natural opinion, and it prevailed during the whole of the long subsequent reign of phlogiston. It not only lasted, indeed, till the time of Lavoisier, but neither Cavendish nor Priestley ever gave it fairly up. The metals are for the most part extracted from what are called calxes, on account of their resemblance to so many chalks of different colours. These calxes, rusts, or earthy ores are endowed with neither the weight nor the lustre of metals. They are as unlike iron, lead, or gold as things can be. Yet it is easy to change them into metals: iron rust into iron, lead calx into lead, and so forth. They are heated along with carbonaceous materials in exclusion from the air, whereupon the respective metals are melted out, and flow to the bottom of the apparatus. Thanks to the Lavoisierian chemistry, we know the meaning of this operation. It is the carbon that carries away oxygen from the ores, and leaves the metals free; for those ores or rusts are composed of that oxygen and the metals respectively. But at first sight, it must have looked as if the ores got some-

thing in the furnace, instead of giving away anything : it must have seemed that they took some principle from the furnace, and so became metals. It required many a long and weary day's work, alas ! to make it even possible for Lavoisier to discover that it was exactly the reverse.

According to Geber and his successors, however, the metals were not only compound creatures, but they were also all composed of the same two substances. Now both Prout and Davy have lent their names to ideas not unlike this. ' The improvements,' says the latter, ' taking place in the methods of examining bodies, are constantly changing the opinions of chemists with respect to their nature ; and there is no reason to suppose that any real indestructible principle has yet been discovered. Matter may ultimately be found to be the same in essence, differing only in the arrangement of its particles ; or two or three simple substances may produce all the varieties of compound bodies.' Those ancient ideas, therefore, of Demetrius the Greek physicist, and of Geber the Arabian polypharmist, are still hovering about the horizon of the most recent system of chemistry.

The Arabians taught, in the third place, that the metals are composed of mercury and sulphur in different proportions. It was at one time a favourite hypothesis of Davy's, that the metallic and other elements are the compounds of hydrogen (a kind of gaseous mercury) with a yet unknown base, in different proportions. He tugged hard at more than one of the elements to prove it. The fact is, that both the polypharmists and he are in error. Mercury and sulphur are just as much (and as little) elementary bodies as silver and gold, lead or tin, copper or iron, on the one hand ; and on the other, the hydrogen extracted from certain so-called simple substances, by the

British chemist, was only hydrogen mechanically condensed within their pores, as he discovered in good time. The oldest and the youngest schools of chemistry, then, are equally at fault in this particular ; and this brings us to the remark, that Geber, Rhazes, Avicenna, Mesue, Averröes, and their compeers, did no more bestow their principal attention upon those speculations anent mercury and sulphur, than Davy or Berzelius expended his labour on analogous hypotheses. They were, in truth, genuine polypharmists ; neither more nor less than is implied in that business-like denomination. They toiled away at the art of making many medicines out of the various mixtures and reactions of the few chemicals at their command. They believed in transmutation, but they did not strive to effect it. It belonged to their creed rather than to their practice. They were simply a race of hard-working, scientific artisans, with their pestles and mortars, their crucibles and furnaces, their alembics and aludels, their vessels for infusion, for decoction, for cohobation, sublimation, fixation, lixiviation, filtration, coagulation, and botherations of every sort. Many a new body they found ; many a useful process they invented ; many a good thing they did. The chief and remarkable difference between these excellent doctors and the young men at work in the *officinum* of a reputable chemist and druggist consisted, perhaps, in the circumstance, that they had a kind of scientific religion over their sweating heads. They believed in transmutation, in the first matter, and in the correspondence of the metals with the planets, to say nothing of potable gold ; whereas their modern counterparts see through every species of humbug—mesmerism, homœopathy, *et hoc genus omne* !

Whence the Arabians derived the sublimer articles of

their scientific faith, is not known to any European historian. Perhaps they were the conjectures of their ancestors according to the flesh. Perhaps they had them from the Fatimites of Northern Africa, among whose local predecessors it has been seen that it is just possible the doctrine of the four elements and their mutual convertibility may have arisen. Perhaps they drew them from Greece ; modifying and adapting them to their own specific forms of matter, mercury, sulphur, and arsenic. But be those high dogmas the direct produce of Arabian thought, or be they a cross between Greek ideas and Arabian facts (an opinion to which we incline), there they are ; and they must now be traced into European alchemy.

Partly carried by the Moors by way of Africa, and partly borne by the currents of returning Crusaders, this Arabian chemistry was brought to Europe ; and it speedily became inextricably entangled with the fantastic subtleties of the scholastic philosophy. It was in Spain that it found its earliest opportunities of this new and not uncongenial development. It flourished there, in an unprogressive way, under the patronage of the Ommiades ; but not until the tenth century. It spread from Spain to England, Germany, France, and Italy successively, from the eleventh to the sixteenth centuries inclusive. It is interesting to learn that the earliest authentic works of European alchemy now extant are those of our wonderful countryman Roger Bacon ; or, as the name imports, Roger Beacon, a word which is pronounced Bacon in some districts of England yet. In fact, he is the foremost man in all the school ; the first in substantial knowledge, and the greatest in faculty. He was born in the county of Somerset, in the year 1214, and he lived seventy years.

Having studied at Oxford and Paris, he became a Franciscan friar. Little is now known about his outward life and conversation. The people suspected, dreaded, and slandered him. He was accused of having fabricated a brazen head, according to the rules of the occult philosophy and judicial astrology, which uttered oracles to him when consulted by magical incantation; he was imprisoned more than once; and at last he was poisoned by his monastic brethren. A man of vigorous and erected intellect, he saw far before his age. In a book concerning 'The Wonderful Power of Art,' he condemns magic, necromancy, the doctrine of charms, and all such things. Acquainted with the Latin, Greek, Hebrew, and Arabic tongues, he exhausted all the real physical knowledge of the day. So passionate an instinct had he for what is positive in science, that in the department of nature he actually claimed an equal rank for observation with reason; a claim which was advanced again, and achieved, nearly four hundred years after, by his more illustrious but not more sagacious namesake, Francis Bacon, the liberator of the sciences.

To say nothing of his philosophical ideas and his other information, in chemistry he was acquainted with gunpowder. In giving the recipe for its preparation, however, he expresses charcoal by a word of his own—*luru vopo vir con utriet*; either with the view of hindering so perilous a substance from being made by the vulgar, or for the purpose of slurring over his own ignorance of the ingredient in question. In fact, gunpowder seems to have been known to the Chinese before the Christian era. Bacon asserts that the thunder, lightning, and magic, witnessed by the Macedonians at Oxydrakes, when besieged by Alexander, were nothing but the fulminations of that mixture. It was not introduced into Spain by

the Moors, however, until 1343 ; and it is therefore probable that the friar derived his incomplete acquaintance with it from his Oriental readings. He believed in the convertibility of the inferior metals into gold ; but, like his Eastern teachers, he does not profess to have ever effected the conversion. He was eminently practical in the tendencies of his mind, although he retained some of those speculative views which we have seen to be deficient neither in sublimity nor in a species of truth. His faith in the elixir of life was somewhat deeper rooted than his confidence in gold-making. He followed Geber in regarding potable gold—that is, gold dissolved in nitro-hydrochloric acid or aqua-regia—as nothing less than that terrestrial hypocrene. Urging it on the attention of Pope Nicholas iv., he informs his Holiness of an old man who found some yellow liquor (the solution of gold is yellow) in a golden phial, when ploughing one day in Sicily. Supposing it to be dew, he drank it off. He was thereupon transformed into a hale, robust, and highly-accomplished youth. Having abandoned his day-labouring, he was received into the service of the Sicilian king, and served the court some eighty years. The philosopher, it is to be presumed, must assuredly have taken many a dose of this golden water himself, and, if the Grey Friars had not made away with him, he might therefore have been alive at this moment, as stout a positivist as Monsieur Comte ! At all events, it is curious to think that Descartes, the father of psychology, regarded by many as the inventor of the inductive philosophy, and the rival of Bacon the Second, should have been as credulous as Bacon the First about long life. Descartes also believed he had attained to the art of living a few hundred years, and so did some of his friends. When he died before reaching the climacteric of sixty, nothing would

convince one of his most intimate associates that he had not been poisoned. In truth, we should never look at the little particular beliefs and notions of great spirits in the history of science, but to their great ideas, otherwise we shall run the risk of despising men so exalted in character as to remain for ever incapable of despising us. But, some thoroughgoing Baconian will perhaps observe, it is important to take notice of the ridiculous opinions to which their wrong method was able to conduct such men. Well, one might reply, be just, and apply the same scrutiny to the second Bacon and ourselves; for the day will soon enough be here when posterity will smile at the Baconians of the eighteenth century, who brought themselves to think of the Bible, for example, as nothing more than an organon of priestcraft; at the positivists of the nineteenth, who discovered that thought, emotion, passion, and will, are but the imponderable products of chemical or other physical actions in the brain; at the physicists of to-day, who have entertained such images of the materialising fancy as the matter of light, caloric, electric fluids, and what not! Perhaps the time is not distant when young children will wonder at not a few things belonging to the truth of ingenuous observation, which we are yet slow to receive; for credulity of temper is even more strikingly exemplified in bigoted unbelief of the credible, than in too great a facility of conviction. In fine, there is probably as much nonsense believed, and as much truth rejected, in these our own times, as at any other period. But it must never be forgotten, that there has also been accomplished a vast increase of real and positive knowledge in the progress of these centuries; that increase being quite as much owing to Roger Bacon and his compeers as to us; for their part of the task was a far harder one to perform

than ours. There is indeed no room for national or epochal vanity in the study of the history of science ; there is rather occasion for humility and emulation ; for those old men worked with grand ideals and small means upon an obdurate and an unbroken soil, while we stand on fields which they have ploughed, armed with an elaborate instrumentation, and too often guided by ideals which savour more of the shop than of the universe.

The next great name in the authentic history of alchemy is a German one. Albrecht Groot, or Albertus Magnus, was born at Bollstadt of Suabia in 1193, some twenty-one years before Roger Bacon ; and he died two years before him ; but he was rather later than the friar as an author. Remarkable for his early appearance of stupidity, he studied medicine at Padua, and taught it at Cologne and Paris. He then travelled all Germany as provincial to the fraternity of Dominicans, and so-journed at Rome some time in all the odour of renown. He was finally appointed to the bishopric of Ratisbon. A theologian, a physician, an astronomer, a magician, a necromancer, and not a little of the man of the world, he addressed himself with particular emphasis to the study of the polypharmacy of the times, and wrote many works on that and other cognate subjects. He describes the chemical water-bath, the alembic, the aludel, and various lutes ; and shows himself acquainted with alum, caustic alkali, the purification of the royal metals by means of lead, and the purging of gold by cementation, to say nothing of his knowing how to determine its purity. Red lead, arsenic, and liver of sulphur, are among the chemicals on which he multiplied experiments. His style of exposition is generally plain and intelligible. In addition to the sulphur-and-mercury

theory of the metals, drawn from Geber, he regarded the element water as still nearer to the soul of nature than either of these bodies. He appears, indeed, to have thought it the radical source of all things, along with Thales, the father of Greek speculation. Like all the true masters, however, he was more of a workman than a visionary.

Thomas Aquinas, the Dominican, was a pupil of Albrecht's. A divine and a scholar, that canonised personage wrote several obscure treatises of alchemy. He is chiefly notable here, however, as having first employed the word 'amalgam.' Quicksilver penetrates tin, lead, silver, and some other metals—opens them up, and makes a homogeneous paste or liquid with them. Aquinas denominated the resulting compound in such cases an amalgam.

Raymond Lully is said to have been a pupil of Friar Bacon's. He was born at Majorca in 1235. His father was seneschal to James I. of Arragon. He entered the army very early in life, whence he soon passed to court. Being yet young, and having subsequently studied at Paris, he became not only a doctor, but likewise a member of the order of Minorites; and he persuaded King James to found a cloister of his ecclesiastical brethren in Minorca. He journeyed through Italy, Germany, England, visiting kings' courts and rich abbeys, for the purpose of rousing Europe to one grand missionary effort for the salvation of the heathen. It is said that he was never a whole year in one place from his youth upwards. He visited Cyprus, Armenia, and Palestine, in the character of an impassioned preacher of Christianity. According to one account, he was stoned to death on the coast of Africa in the course of a sermon; but according to another, he died at home in 1315, at eighty years of age,

having sunk into fatuity before that event; and he was buried in his native isle. Notwithstanding this impassioned and erratic career, he dabbled industriously among the chemicals of the time, and produced more than sixteen chemical works. They are much disfigured by unintelligible jargon, and present a powerful contrast to those of Roger and Albrecht in respect of vigour and common sense; yet he was the first to introduce the use of chemical symbols, his system consisting of a scheme of arbitrary hieroglyphs. Nor are his books deficient in observation. They contain many observations on the distillation of cream-of-tartar; the deliquescence of the alkalis; the separation of aquafortis from saltpetre by means of the oil of vitriol; the preparation of aqua-regia by mixing nitric acid with sal-ammoniac or common salt; the volatile alcali; alum; marcasite of some sort; white and red mercurial precipitates; and other things. He made much of the spirit of wine, imposing on it the name of *aqua vitæ ardens*, which it retains to the present time in some quarters. In his enthusiasm he pronounced it the very elixir of life, an opinion which is still a favourite among our countrymen in the north. In a word, he was a restless, intelligent, inventive, and somewhat fanatical busybody in the affairs of the Church, of science, and of life; an ardent and generous spirit withal, probably not unlike our own Priestley, and not without a great degree of utility in his day and generation.

Arnoldus de Villâ Novâ was not a churchman like his predecessors. On the contrary, he was condemned as a heretic, but the Pope protected him from the extreme penalty; as the Pope of his day would have consented to protect Galileo, if the impetuous Tuscan would only have suffered himself to be advised. Born in Provence,

somewhere about 1240, and educated under the famous John Casamilla at Barcelona, he had to flee to Paris through Italy for forecasting the deathday of Peter of Arragon. He afterwards taught in the university of Montpellier, and was consulted far and wide by kings and popes. Guided by the rules of judicial astrology, he discovered that the world was to have been blown up in 1335; a discovery which is surpassed by soothsayers of another species, almost every month of every year, in these more illuminated days of ours. Unable, however, to await the fulfilment of the horoscope he had drawn out for the Mighty Mother, he died in 1313, on his way to visit Clement v., who was lying sick at Avignon. He wrote twenty-one works; of which the *Rosarium*, a compend of alchemy, is the most curious, if not instructive. The theory of the author is very plain, but his practical directions are far from lucid now. Mercury is an element of all the metals. Gold and gold-water are the most precious of medicines. Bismuth is called marcasite. The preparation of the essential oil of turpentine, the oil of rosemary, the spirit of rosemary, long known as Hungary-water, and many other gentle distillations, are all to be traced to this heretical experimentalist.

A couple of Dutchmen are the next to figure in this alchemical calendar—Isaacus Hollandus, and either his brother or his son. These Hollanders belong to the thirteenth century, later in the day than Arnoldus, whom they quote with reverence. Their treatises are remarkable for clearness and precision. They were the first to give figures of apparatus—a thing which renders their works memorable in the history of physics. Writing mostly in Latin, they sometimes used the German tongue, being probably the earliest vernacular authors in European

science—another claim to distinguished remembrance. With all their plain dealing and plain speaking, however, they cannot be said to have advanced chemistry otherwise than as honest, sagacious, and penetrating compilers. It is curious that your clear, cautious, ultra-sensible men do so very little that is new and great. It would appear that vigorous impulses, and a certain poetical extravagance of character, are quite as characteristic of the Keplers, the Hunters, the Herschels, and the Davys of science, as even that cardinal faculty of the soul, that first and last of the intellectual virtues, common-sense itself.

These qualities were combined in an excellent proportion in the person of Basil Valentine, one of the most celebrated of all the alchemists. Born at Erfurt, a Saxon town, in 1394, he became a Benedictine monk. He bestowed the larger part of his attention upon the preparation of chemical medicines. It was he who introduced antimony into medical use; the 'anti-monk metal,' the name assigned it, one might surmise without uncharity, after some wicked experiments on the stomachs of his monastic brethren. He made a vast deal of that curious metal. All he writes about it is as clear as glass, and quite abreast of our knowledge in the present century, so far as it goes. He makes no mistakes so long as he treats the chemistry of the subject. The *Cur-rus Triumphalis Antimonii*, or 'Triumphal Chariot of Antimony,' were almost a model of positive observation, if it were stripped of its chemico-medical speculations. Drawing a beautiful but fallacious analogy between gold-making and the restoration of health, he maintains that antimony is the best for both! He followed the Hollands in regarding salt, sulphur, and mercury as the three bodies contained in the metals. He inferred

that the philosopher's stone, or peristrophè, must be the same sort of combination—a compound, namely, of mercury, sulphur, and salt ; so pure that its projection on the baser metals should be able to work them up into greater and greater purity, bringing them at last to the state of silver and gold. But Basil Valentine, the steady-eyed charioteer, knew something more substantial than these things. He knew arsenic and its red sulphuret, zinc, bismuth, manganese ores, nitrate of mercury, corrosive sublimate, red mercury, nearly all the antimonials in the pharmacopeias of 1851, litharge, sugar of lead, white lead, and many things besides, under these or other names. He precipitated iron from solution by potash. He was aware that tin sometimes contains copper, and that Hungarian silver contains gold. He knew how to extract gold from the red elixir, by means of quicksilver, and he makes mention of fulminating gold. In fine, he may be characterised as the founder of analytical chemistry, that inevitable art which now leaves nothing untouched ; which is furnishing new wonders every year ; which resolves the food of nations into water and air, and suggests the possibility of air and water being some day made into food ; which is drawing nigh the very threshold of vitality with fearless hands ; and which is undoubtedly destined to change the whole economy of the outward life of man.

Roger Bacon having thus set the example of enormous industry, and having exalted experiment to its legitimate rank in the logic of chemistry ; Albrecht Groot having supported the dignity of the science by the universality of his accomplishments and the elegance of his style ; Arnold having applied the art of common distillation to chemical research ; Raymond Lully having summoned

the attention of the adepts to the products of destructive distillation ; and Basil Valentine having opened up the science of metallurgy and analysis, there came upon the field a gigantic creature more celebrated than them all : it was Paracelsus. As strong-headed as Bacon, as inventive as Albrecht and Arnold, as indomitable as Lully, and as mighty an enthusiast as Basil Valentine, this remarkable man wanted the truthfulness of character which animated all his predecessors ; and he fell. He was born near Zurich, at the beginning of the sixteenth century, his name being Theophrastus Bombastes ; and it is from that surname that the word ‘ bombast ’ is derived—so arrogant, so insulting, and withal so ‘ great and swelling ’ were the ‘ words of vanity ’ he uttered, when little Theophrast grew a famous revolutionist under the far-sounding title of Theophrastus Aureolus Bombastes Paracelsus ! His boyhood and youth appear to have been engaging, though impassioned and ambitious. He began life as a purist, having drunk nothing but water, and eaten little else than bread, until he was appointed to the professorship of chemistry at Bâle in 1527, the earliest chair of chemistry ever established. As a physician, early famous, he was amazingly successful and amazingly presumptuous ; as a professor, he was eloquent, learned, and insolent in the extreme. He burned the books of many of the authorities before his hustling crowds of students ; poured his contempt upon both the Arabian shop-doctors and the scholastic pedants ; sounded anew the praises of Hippocrates ; magnified his proper self even more than the sagacious Greek ; played all sorts of mad pranks ; surcharged his fascinated disciples with his overweening spirit ; and kept up such a storm in poor little Bâle, that at last he was compelled to abdicate his chair and flee. After

many alternations of fortune, and after having abandoned himself to debauchery, this 'erring and extravagant spirit,' this man of extremes, this mighty agitator, actually died in an obscure tavern at Salzburg, at forty-eight years of age. We may lament his ungracious life and his miserable end ; but there is no denying that he was a great reformer ; and he is certainly an important figure in the history of chemistry and medicine. He descried the utter hollowness of the prevalent scholasticism, as respected physical investigation, with an eye as clear as Francis Bacon's. On the other hand, he looked with the contempt of a Carus or an Oken on the bootless ploddings of the mere pharmaceutical chemists of the day. He also perceived the value of the long-neglected descriptions and practical rules of Hippocrates, with the sagacity almost of a Sydenham or a Cullen. In truth, if he had been content to do these three things, and to do them well, he might have become the father of modern science ; but Old Legion was in him, and he could not govern his noble intellect. Ambition, vanity, the love of opposition and destruction, and all unkindliness would not let him be. He would amaze as well as instruct the world, forsooth ! He would put it under everlasting obligations to him, while he despised its gratitude ! Athirst for true glory in his earlier years, he early became the victim of a lowlived hunger for power and reputation. The great positive aim of his efforts was to pluck the panacea or elixir from the secret-keeping heart of nature, and thereby show how omnipotent he was. He did not succeed of course ; but he was too proud to own his failure, and so he talked 'an infinite deal of nothing.' What with private brawling, public haranguing, and ceaseless publication, the student feels as if this magnifico had only talked and talked, and died in

ignominy. Yet he was a vigorous thinker, and actually originated a practical movement in our science, while he certainly brought mere alchemy to an end. Holding by Basil Valentine's principles of mixts or elements of compound bodies, salt, sulphur, and mercury (representing respectively earth, air, and water, fire being already regarded as an imponderable), he generalised the properties of those four first principles of nature with great breadth. They were purely representative in his system of doctrine, as their counterparts had soon become in the systems of the Greeks. All kinds of matter were reducible under one or other of those typical forms: everything was either a salt, a sulphur, or a mercury; or, like the metals, it was a mixt. There was one element, however, common to the four; a fifth element, the quintessence of creation; an unknown and only true element, of which the four generic principles were nothing but derivative forms or embodiments. In other words, he inculcated the dogma that there is only one real elementary matter—nobody knows what; a dogma like that of Demetrius and Aristotle, which is metachemical rather than chemical, and therefore of little or no practical importance. It gave his experimental pursuits a useful bias, however. It set him upon the search after the essences and quintessences of things. By a natural, but no less sophistical slip in his logic, he considered alcohol as the quintessence of wines; and blue as the quintessence of blue stuffs and stones! It was in this way, however, that he set agoing that prosecution of the active principles of mixed or complexed medicaments, which has ended in the extraction of quinine, morphia, veratria, thëine, and a multitude of valuable proximates. It was Paracelsus, also, who began that tendency to mingle chemical considerations with the physiology of

the human body in health, with its pathology in disease, and with the practice of the art of healing; a tendency which is still far from being exhausted. The works of Dumas and of Liebig, and of the whole school which they represent, may be described as the very consummation of this iatro-chemistry, as it has been styled. It was likewise our present hero who introduced the word *alcahest* into alchemy, the term usually applied to the universal solvent; a word supposed by some to mean *alcali est*, is it an alkali?—but sometimes said to be composed of the two German vocables, *alle geist*, all spirit. It does not appear that Bombastes was a seeker of this universal solvent himself; but the name perhaps imports his idea that the one prime element of things, or fontal matter, was also the veritable alcahest. High above his practice of physic, his criticism of the predominant methods of inquiry, and his multifarious manipulations, there seems to have flitted the sublime conception of an unattained, perhaps an unattainable, quintessence or fifth element of things, which should prove to be at once the philosopher's stone, the universal medicine, and the irresistible solvent. In order to seize this triple aureola of existence, and put it on his heavy-laden head, as a crown of joy, he knew that it behoved him, at the very least, to lead the natural life of a child in the intellectual life of a free man; but he paltered with his idea of his mission, sank into infamy, and died unannealed. Yet something that is charitable and thankful, and even affectionate, is surely to be pronounced over the squalid public-house where so magnificent, so outspoken, so effective; so celebrated, and withal so wretched a Protester fell asleep at last. But that is a task for the orator or the poet rather than for the man of science; and the reader is therefore referred

to Browning's philosophical drama, entitled 'Paracelsus,' for the emotions with which it becomes us to pronounce his motley but splendid name, and to remember his stormy but beneficent career.

We have now considered the ideas of the Greek physiologists concerning the world of matter, in so far as they are capable of being represented as standing in connexion with the history of early chemistry; having omitted taking any notice of the atomic theory of Democritus, because it has no relation to that history until the time of Dalton, our own contemporary. We have also glanced at the nature of Geber and the Arabian polypharmists, and seen as far into them as Sprengel and other authors have enabled us to do. We have likewise spoken briefly about the series of grand-masters in that dim and somewhat free-masonic department of scientific history—European alchemy,—from that proto-martyr of science in Christendom, Roger Bacon, down to Paracelsus, the magnificent victim of his own presumption and the hatred of his age; and found them to be for the most part a race of brawny inquisitors, inspired by ideas great enough to enable them to live aside from the world, if not above it, on the one hand, and to do a good day's work for the world, on the other.

To take the ludicrous view of the character of these Arabian, English, Spanish, German, French, and Dutch enthusiasts for a moment, it was of such men that the fantastical Beccher exclaimed—'*De gustibus non disputandum est*—There is no disputing about tastes;' a proverb which agrees with reason and experience. Some folks will have sweet food, others like sour better, and a third prefers what is bitter. Some delight in gaiety, some in sadness. Some love music, others have no

pleasure in it at all. But who would have thought that there is a taste to which you must sacrifice honour, health, fortune, time, and even life? You say that those who are addicted to it must be madmen. No! They are only men of an eccentric, heteroclitic, heterogeneous, abnormal turn of mind. They are chemists—

‘Nasty, soaking, greasy fellows,
Knives would brain you with their bellows;
Hapless, sapless, crusty sticks,
Blind as smoke can make the bricks!’

Chemists of lively parts and wide views, such as Joachim Beccher was, must sometimes make a pause in the toilsome career of their life in the laboratory, and smile at the grim earnestness with which they hang over their furnaces, batteries, mercurial troughs, Bohemian tubes, thermometers, and balances, denying themselves the freedoms of nature; and many of the dearer interests of other men. There are poets who wonder at the spectacle of such keen spirits as Humphry Davy, for example, labouring with might and main at the dry births of stone and iron, when they might well be abroad among the strong and the beautiful, stirring the life of man in its august depths. But a man must work where he is placed; and he must also obey the hint of his peculiar talent, else he will never do the most he can for the race and for himself. These are two of the great rules of duty. There is little matter what a man finds to be his proper task, so he rest not until he have won all it can teach him; so he relax not until he have made the most of it for the world; so he relent not before he has adorned it with his proper virtue, and ennobled it by his proper genius. Truth is a globe like the world; and it is of small moment where you begin to dig, for you will come as near the centre as another if you dig deep

enough. It is at the same time an important, though a secondary duty of the industrious miner, to ascend every now and then from his particular shaft, both to see what others are about, in case he should become the egotist of a single pursuit, and to refresh himself with the inexhaustible variety of nature and of life.

To return to the alchemists, who were wiser in this very respect than their successors in these days of the extreme division of labour, the historian finds that soon after Paracelsus the adepts of Europe spontaneously fell into two classes. One of these comprised a multitude of weak men, who rode the hobby of the older school ; and that very hobbihorsically too, to quote a whimsical adverb of Sterne's, for the purpose of characterising a set of whimsical fellows. The other class was composed of men of diligence and sense, who devoted themselves with infinite labour to the discovery of new compounds and reactions. The two constituent elements of the genuine alchemist, in fact, fell asunder after Paracelsus ; and both of them suffered from the separation. The fantastical element found a host of foolish representatives, and the practical one incarnated itself in a company of plain and painstaking men. The celebrated Van Helmont was an enthusiastic alchemist in his youth, and a thoroughly practical chemist in his old age. Nor can it have been an easy thing for such as he to renounce the sublimities of alchemical ideal, and content themselves with the practicable aims of common chemistry. Van Helmont had actually convinced himself that not only gold—that sun-bright and almost beatified body of the soul of matter—but everything else, consists essentially of nothing but water, as had been told the ancients by Thales, the eldest of the seven wise men of Greece. He had planted a sprig of willow in a vesselful

of such a soil as appeared incapable of yielding it any nutriment; suspended the little willow and its pot in the air: fed it on pure water; and yet the creature had grown apace, stretching forth its branches, and covering itself with leaves. What was to be inferred from this seemingly crucial experiment? Why, surely that wood, and bark, and foliage, and acids, and salt, and earths, and all things do lie folded up in some mysterious but not inscrutable manner within the elemental substance of water. Alas, the experiment was fallacious! The experimentalist did not know that the air around his expanding plant contains both carbon and nitrogen; that water results from the union of oxygen and hydrogen; and that these three gases, and that one solid body, are in reality the essential constituents of the vegetable tissue. Van Helmont, however, must on the whole be regarded as belonging distinctly to the new school of practical chemists, and not to the post-Paracelsian brotherhood of degenerated alchemy. It must be confessed, at the same time, that the chief circumstance which lent any dignity to the pursuits of him and his companions in arms, was the stupendous chaos of phenomena in which they had to work. Libavius Cassius, Glauber, Agricola, and the rest of them, deserve to be remembered for their indefatigable zeal, and for the multitude of single facts they managed to quarry out of nature. It has also to be recorded of them that, although they were a race of pedantic artisans rather than men of science, it was more particularly in their persons that the metaphysical era of scientific history was aspiring towards a more exalted stage of development; namely, towards the epoch of positivism, the era of Descartes and Bacon, the day of experimental observation under the guidance of the inductive syllogism.

It is unnecessary to trace the alchemists, so called, after this decomposition of the old alchemical character. They are no longer historical ; they are no longer with their age ; they are behind it. The vitality is gone from them ; they merely drivel on in a kind of questionable existence. They are poor ghosts, being *restants* that cannot get away ; not *revenants* come back with some important secret. The life of the time is all on the side of the practical chemists after Paracelsus. The misnamed alchemists are mere inanities after that period. They can do no one useful thing ; they can only compile mystical trash into books, and father them on Hermes, Aristotle, Albertus Magnus, Paracelsus, and other potentates that never wrote such nonsense in their lives. They can only form themselves into secret associations, Rosicrucian fraternities, and what not. Yet it was this wretched remnant of a great school that gave the earlier men of the present age its impression of alchemy. Now, visionaries of this cast exist in 1851. There are actually a number of as genuine scientific fanatics as these, possessed by the very same fantasies, and using the self-same phraseology, astrological and pseudo-alchemical, in the Europe of the present day ; but no one would ever think of according any historical significance to such a second nursery of innocents as that. Yet the sole difference between these poor creatures and the post-Paracelsians of the seventeenth century, is to be found in the circumstance, that the latter had many temptations and opportunities to play the Dousterswivel ; and accordingly many a strange imposture was then practised in the name of Aristotle, Geber, or Raymond Lully. One might relate innumerable stories of that sort ; but it is impossible to see how such narratives could be of the slightest use towards the

right understanding of true and historical alchemy, from Friar Bacon to Paracelsus inclusive.

It is enough to notice the fact, that after Paracelsus's protest against the intellectual methods of old alchemy, a multitude of weaklings continued to dream away their lives among the verbiage of an exhausted movement in all countries ; while a race of sturdy, positive chemists were living to some useful purpose, and finding out all sorts of new chemical substances in preparation for the unpretending logic of a better day. The two streams, like the unmingling waters of the Saône and the Rhone, ran together a space side by side before dividing for ever : one of them to sink into the sands, like Arethusa, and be lost ; the other to gather a hundred tributary streams, and come flowing right onwards. Alchemy has, accordingly, be it repeated, no historical meaning—one might almost say, no historical existence—after Paracelsus ; just as the critical doctrine of Voltaire and the Encyclopædists cannot boast of anything like a historical life in Europe after the close of the last century, although there are still men in Paris, Berlin, and London, who will swear by it to the last. Nor would the historian ever dream of illustrating the scepticism of the senses from the timid and feeble performances of those fond and lingering disciples of that inverted psychological alchemy of the eighteenth century : inverted alchemy, for its 'grand projection' consisted in the attempt to transmute everything into nothing ; reminding one of that unhappy votary of Rosicrucian vanity, who chronicled the sad result of all his life in one melancholy couplet—

' From out of nothing God fetched everything,
But out of all poor I can nothing bring !'

Yet it appears, as has just been said, that the current

notions of alchemy are drawn from the etiolated and party-coloured literary remains of those posthumous votaries of the spagyric mystery. It is from that too questionable epoch, for example, that we have the story of a venerable stranger entering the famous city of Nobody-cares-what at eventide, in the grey month of November, in the memorable year 1600 ; of his inveigling the ingenuous son of his landlord into recondite talk anent the stone ; about their going privily to a great rich goldsmith, and making a huge ingot of gold out of tin and lead with his utensils ; of their selling it at a just price to the hospitable jeweller ; and of the venerable rascal stealing out of the city before cock-crow with all the good money in his pocket. It was during the same period, in fact, that quackery and imposture abounded in connexion with mock alchemy. It was then that ape-headed, nut-hearted, sly knaves easily found their dupes among fools in high places, as avaricious and ignoble as they were credulous. It was then, to take an instance, that the former scamps made up large nails, half of iron and half of gold, well joined together, and varnished with lacker, so as to pass for the baser metal ; and then that the latter equally wretched creatures opened their eyes with amazement, and their hands with greed, when they saw a good golden ingot extracted from plain iron !

It was then, also, that the majority of the accessible alchemical tracts and treatises were compiled. The miserable anonymities who put them together generally inscribed the name of some grand authority upon these inane productions, to give them currency. They consisted for the most part of the wilder passages of old masters, unaccompanied by any of their real knowledge and practical remark, mangled, inflated beyond bearing,

and maddened by the poor cross-lights of the actual editors. The reader accordingly comes upon striking and even beautiful passages in some of those performances, which are frequently just so coherent, and no more, as to suggest the perception that there is a 'method in their madness.' For example, one of some score of masquerading Paracelsuses opens his creed with these words:—'All composed things are of a frail and perishing nature, and had at first but one only principle. In this all things under the cope of heaven were enclosed, and there they lay hid; which is thus to be understood—that all things proceeded out of one matter, and not every particular thing out of its own private matter by itself. This common matter of all things is the great mystery, which no certain essence or prefigured idea could comprehend. Nor could it comply with any property, it being altogether void of colour and elementary nature. The scope of this great mystery is as large as the firmament. And this great mystery is the mother of all the elements; the grandmother of all the stars, trees, and carnal creatures.'

Such is the preamble of the book; but nothing follows; for the substance of the treatise is just this same preamble, with variations over and over again. The penman's science is like a street-organ of old and even elaborate construction; but all its tunes are gone dumb except this one; and for the life of him he can grind nothing out of it but the overture.

The true alchemists, then, while they were also diligent experimentalists in pharmaceutical and other practical chemistry, cherished three sacred beliefs and objects of enthusiastic hope, which we shall now arrange not in their historical, but in a convenient order.

I. They believed in the alcahest, or universal solvent. Taking that epithet even in its most literal signification, it has simply to be stated, that modern chemistry has actually realised it. The element fluorine is nothing less than the alcahest. Lavoisier once expressed his surprise that it should never have occurred to the masters that no vessel on earth could hold the universal solvent, because it would solve the vessel too. That is precisely the difficulty to contend with in the attempt to isolate fluorine. It is a good many years now that it has been well understood by chemists that Derbyshire spar is composed of calcium—the metal of which quicklime is the oxide—and of fluorine, another element, the latter of which ingredients could not be presented separate, just because no substance could withstand the intensity of its chemical action. No one doubted the existence of fluorine—thanks to Davy's discovery of iodine, and the sagacity of Ampère—notwithstanding the circumstance that it could not be handled and seen, owing to its irresistible powers of solution. It at length occurred to two brothers of the name of Knox, that vessels cut out of fluor-spar itself, seeing it is a substance already saturated with fluorine, might serve the purpose of isolating fluorine; and their experiments have been in a great degree successful. Faraday has also experimented on this subject. Fluorine seems to be an orange-coloured gas; chlorine is a green gas; iodine is a solid at ordinary temperatures, but a gentle heat converts it into a deep purple vapour. Bromine is liquid, and resembles iodine vapour when in the gaseous state; but it is more ruddy than purple. These four elements are deeply connected with one another; but be that connexion what it may, and even suppose that fluorine has not yet been separated in the state of absolute

chemical purity, it cannot be denied that there lies the alcahest of old alchemy.

II. They believed in the transmutability of metals ; it has already been seen on what kind of grounds. The idea of transmutation, stripped of all particularity of form, is old as Thales and recent as Davy, to profane this page with no meaner name. In one shape or another, it is ineradicable from the instincts of the science. It is hardly necessary to add, that if any one element were satisfactorily converted into any other, this the second problem of alchemy were solved as well as the first.

III. Those European alchemists also believed in the elixir of life, or universal medicine, capable of curing all curable diseases, and of prolonging life far beyond its present average of duration. It was not till the dotage of alchemy that the conception of an elixir of immortality amused the world. In connexion with this unattainable ideal of theirs, it has just to be mentioned that Lord Bacon and Descartes, who are always regarded as the Castor and Pollux of that luminous epoch of science which extinguished the mediæval schools, were quite as much bent upon the invention of means for the prolongation of life as any alchemist of them all. We have already seen that the French methodologist actually supposed himself to have added a few hundred years to existence ; and anybody that has read Bacon's precepts on the subject, will testify that the elixir-hunters could not exceed him either in the largeness of his expectations or in the absurdity of his plans. Neither is it very easy at first sight to perceive the practical superiority of the successive medical schemes of Stahl, Boerhaave, Cullen, Broussais, and the rest of the modern doctrinaries, over those equally successful and more poetical dreamers. If a scientific spectator may judge from the recent writings

of certain of our own physicians—from the articles and letters, for example, of Dr. Forbes, the editor of the *British and Foreign Medical Review*, of the late Dr. Andrew Combe, and of a host of anonymous abettors of these able men,—the predominant school of physic appears to be coming to the conclusion, that it can scarcely do better than go back to the time of Hippocrates, sit a while at his feet, and begin afresh. It is the very counsel which poor Paracelsus thundered into the astonished and insulted ears of his contemporaries.

Such, then, was alchemy; such the heaven, the horizon, and the neighbourhood of the third of the ancestors of the modern chemist. To the man of the nineteenth century, it must always be interesting to grope away back into those dim and spectral regions of scientific development. Were circumstances favourable, we should be glad to accompany the student into some of the more quaint and questionable of those recesses of the past. We should visit the weak as well as the strong; for there were the weaker brethren in those religious days of science as well as now. What buried figures we should descry, intent with sweating brains upon the last projection; what minglings of the glare of the furnace with the unearthly glow of a magnificent but misdirected spirit of enthusiasm; what perilous balancings of the spirit between the dread extremes of imposture and insanity; what thin lights and solid shadows we should behold in the murkier hours of that merely starlight night of history; what agonies of mind and heart! Ideals how sublime, realities how paltry! It was their lifelong struggle to bring a lofty but imperfect theory of nature into effective unison with the inflexible phenomena of the world of facts. They did not succeed, and they have passed away. Peace be with

them ; for alas ! the life of the visionary is the same feverish, uncalculating, unsatisfying, weary, and maddening discipline in all ages ; and there are as many of those not unlovely maniacs in the epoch of Chancellor Bacon and Humboldt as ever there were in that of Friar Bacon and Paracelsus.

III.

PHLOGISTON AND LAVOISIER.

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THE polypharmists of the Arabian school of medicine, and the alchemists of mediæval Europe, followed ideas so transcendental that, in so far as their ever-vanishing aims were concerned, they at first sight seem to stand in no true historical relation with the moderate and practical chemist of the present century. The seeking for the alcahest or universal solvent, the attempt to extract the elixir of life, the effort to lay hands on the philosophical stone—and that among the mist and darkness of a time which was rather the night than the morning of science—were things essentially unlike the sober and attainable aims of our own positive chemistry; and the men of our laboratories could have taken little interest in the labours they involved, had it not been for the fact that those old scholastics, chasing images they were never to seize, worked out thousands of incidental results. If they went after the illusions of the dawn, shaped out of the murk by the twisted rays of a sun which was yet far below their horizon, it was on the solid ground of nature that they sped their weary hunt; and many a trophy they found lying in the twilight, ready for their early hands, sometimes dazzling them into false perception again, but always rewarding their pains. If they were fond idealists, if they were visionaries, they were also chemists; and it is as chemists that

they deserve the recognition of the world. They worked with water, they worked with fire ; they digested, boiled, distilled, roasted, burned, smelted, crystallised, set agoing putrefactions and fermentations ; in short, they put in operation the same sorts of processes upon the same sorts of stuff as ourselves. Following their hereditary and antique elemental ideas, they were the first discoverers of those material principles and compounds which are commonly called chemicals. Trying to scale the heavens, they began to subdue the earth. It has been already remarked, indeed, in the preceding paper, that those of the polypharmists regarding whom there is any information extant, seem to have been vastly more taken up with their pharmacological preparations than with their panaceal speculation ; while the really great men among the alchemists, from Roger Bacon down even to Paracelsus, were the busy students of such chemical reactions as could then be brought within the reach of the experimentalist, and made no personal pretensions to the Stone. The hypothetical idea of both these successive schools, namely, the transmutation or elevation of the metals, and the analogous elevation of man's fallen and sickly body into the state of golden health, seems at all times to have been a very separable thing from the everyday occupations and practical hopes of the higher order of adepts ; although it certainly vitiated their observations not a little, and corrupted the phraseology of their works through and through, if it did not in some degree demoralise their intellectual habits. Soon after the insolent, but gallant and imperative protest of Theophrastus Aureolus Bombastes Paracelsus, modestly so self-styled, against the pseudo-Aristotelianism of the medical school of his day, the alchemical theory and the alchemical practice of genuine observation in the labora-

tory fell asunder ; one might say, always under censure for a play upon words, that the Arabian particle separated itself by fissiparation from the good Greek noun, if Greek it be ; the oriental Al took itself off, and left chemistry to pursue its own fortunes. The ancient eastern element, however, did not at once disappear from the earth ; for it retained its devotees, no longer respectable because behind their age, till the close of last century, and indeed it has them yet, old half-witted men and younger monomaniacs not a few ; happy creatures ignoring all the results of growing science, and catching at the gifts of nature with ineffectual hands, like ghosts at a feast ! On the other hand, those of the sons of the prophets who at this parting of the ways chose the path of true chemistry, were men of much diligence and sound understandings, and they addicted themselves with zeal to the finding out of all sorts of new chemicals and chemical reactions. Van Helmont, it has been already observed, began life as an alchemist, not in the sinister sense of the word ; but he ended his career as a chemist of some degree of worthiness, although he will perhaps be better known to posterity as the originator of that hypothesis concerning an all-pervading cosmical fluid, which has been elaborated in later times by Mesmer and Reichenbach. Libavius, who came upon the fuming chloride of tin, Cassius, whose purple precipitate of gold is as beautiful and curious as ever, Glauber, whose ‘ wonderful salt ’ is still the friend of horses and horse-doctors, and the sensible though prosy Agricola, deserve remembrance for their industry and the number of single facts they found out ; and it must never be forgotten that it was little better than an unmitigated chaos of things and thoughts, in the thick of which they had to do their poor day’s work. It should also be observed in their praise that, if they

were a kind of learned artisans rather than men of science, it was particularly in their persons that what Comte not happily calls the metaphysical epoch of scientific history was reaching towards a higher stage of development, namely, toward the positive epochal method, the era of Descartes and Bacon, the day of experimental observation and the inductive syllogism.

It will be readily understood how, as soon as the mind of science was withdrawn from aims which were too lofty for its reach, and was unreservedly directed to the positive labours of the laboratory, there would quickly succeed a remarkable extension of practical or concrete chemistry. The only thing that could compensate the emancipated votaries of alchemy for the giving up of their great ideal, and thereby appease the craving of the soul for greatness of some sort or another, was the rapid accumulation of a large mass of new information. Ideal had to be substituted by material wonderfulness, sublimity by size, depth by surface: and it must be confessed even by the lingering disciples of the alchemical mysticism, if such posthumous and undated spirits can turn aside for a moment from their enchanted toils, that the number of solid and liquid bodies, curious for their aspects or for their properties as chemical reagents,—acids, alkalis, salts, mixts, calxes, precipitates, sublimates, essences, oils, butters, and spirits,—which were brought out of nature at this period, was astonishing. It is impossible, indeed, for the most positive and the least speculative of the chemists of the present day, were it even a Rose among his platinum crucibles, or a Plattner with his blowpipe, to overvalue the amount of plain, honest, and sufficient, though merely preliminary, work that was done between the apotheosis of alchemy and the ascension of the phlogistic chemistry.

But that happy, though somewhat meteoric, rise of a new science from the shaken ashes of the old mystery was not long of beginning; for, in the midst of all the gathering and crowding details, wrought out by the post-alchemical craftsmen, a true chemical principle began to gleam. These industrious experimentalists began to understand, once for all, that the act of the burning of a body, or the process of combustion, as it is now called, is a phenomenon of principal significance in chemistry. Perceiving that the interpretation of the burning of a piece of wood, or brimstone, or anything else that is capable of being destroyed or changed by fire, would yield the clue to this whole department of inquiry, namely, to the half-chaotic mass of the chemical discoveries of the period, they invented a theory, or rather a hypothesis of the fictitious sort, capable of rendering the phenomenon of fire intelligible to the mind, but not of explaining it in conformity with the now known reality of things; and it was that memorable hypothesis which constituted or consummated the new movement, and fairly consolidated the second epoch of chemical development. But their doctrine was founded on fact, and it owed all its value to the facts it represented. Notwithstanding the fictitiousness of the point of view on which they eventually planted themselves, they were eminently practical men. They noticed with learned eye that the process of common combustion concealed one of those central facts, on the eliciting of which the progress of science is ever and anon depending. Obedient to the hint of genius, they proceeded to the generalisation of the phenomenon throughout all its known particulars and circumstances. The metals, with the exception of silver and gold, were changed into rusts or calxes, resembling chalk or brick-dust or other

coloured earthy bodies, when heated high in exposure to the air of the furnace; and this alteration they saw to be identical with what is undergone by brimstone, phosphorus, or any common combustile, when it burns with flame. Tin burns with a glow, indeed, which is so like ordinary flame as to have been quite adequate to suggesting the rest of the secret;—no secret now-a-days, of course, since we work in metals that take fire when thrown on water, and think nothing of burning iron wire in oxygen like a wax-match in the air; but a great affair for the early twilight, between the meteors of the alchemical night and the coming sun of positive chemistry, in which it was first made. It was thus, then, that the whole science, such as it was in the first watch of the post-mediæval morning of its now broad day, was divided into distinguishable parts:—the study of bodies before combustion, and that of the same bodies after that great cosmical process. This division of chemical objects implied, as a matter of course, the study of the act of combustion itself. Unburned matter was the thesis, burned matter the antithesis, and the process of burning the mesothesis, of the new logic of chemistry. The matters were as various as nature could afford; they already knew a large number of substances, and undoubtedly anticipated the acquisition of many more: but the process was one and indivisible.

Even this dividing of all the species of matter then known into these two great classes, the burned and the unburned, was most important for the wants of the period; and it is now well understood to have been founded in truth. In a larger sense, it is as true to-day as it was then, that all mineral substances are either combustibles or ashes; and in the smaller sense of those grandfathers of ours, namely, in that of every inorganic

matter being either a combustible or an atmospheric ash (that is, an oxide) it is still correct, in so far as the immense majority of natural bodies are concerned. The chemistry of that time was therefore brought into intelligible order by the generalisation in question ; and all the facts, of which its body then consisted, were thereby made to revolve round one great phenomenon as their common centre. In short, similar things were put together, in spite of their apparent dissimilarity ; and dissimilar things were put asunder, notwithstanding their superficial resemblances ; and a genuine reformation was begun, all with a degree of sagacity far more than equal to the task in hand. But it has already been hinted that those venerable chemists were by no means satisfied with the perception and exposition of the analogy that subsists between the metallic calxes and the acids, nor yet with their new classification of material forms. They advanced, without the infirmity of a doubt, to the explication of the phenomenon of fire itself, that one and universal agent of their chemical transformations. Nor was an interpretation, say rather a figment or a hypothesis, far to seek. The fiction, that fire is a substantial, though subtile, material element of nature, had been promulgated by Empedocles more than four centuries before the coming of Christ : handed down to the polypharmists, it had played but a small figure in their doctrine : brought to Europe once more, the alchemists had written not a little about it and about it, while they had made nothing of it whatever as a theoretic centre : but now it was destined to quicken the whole mass of a growing chemistry, and to give that unity to all its parts, of which they stood more in need than ever. In fine, the ancient Greek, if not Egyptian, matter of fire, the empyrean element of the old quaternion, was at length recognised, set apart and con-

secreted, by the hierophants of a young European science, under the classical name and style of Phlogiston.

Not to trace the hypothesis embodied in that long-lived word with historical accuracy from chemist to chemist, or even from time to time of its existence as a scientific power, let us look at it as an epochal whole, before proceeding to the consideration of the positive chemistry of Lavoisier and his more manly school.

A lighted candle burns till it is done, giving out flame or matter of fire all the while:—for what reason, but because a candle is a compound of candle-matter and phlogiston, because that compound is decomposed when it burns, and because phlogiston is thereby set free and shows itself in the flame from the beginning to the end of the process? The pure dephlogisticated candle-matter is also liberated, of course, little by little as the taper burns from top to socket; that candle-matter turning out to be carbonic acid gas and water, as discovered by later methods of research: so that, according to the phlogistic chemistry, tallow should have been tabulated as a compound of fire with water and fixed air. Counting the ashes of the wick and oil, this was neither more nor less than the experiment of the Greek physiologists after all:—phlogiston or fire, carbonic acid or air, moisture or water, and ashes or earth. But our cunning and well-appointed chemists, as has been said above, generalised the idea all over the enlarging science. A stick of brimstone burns away with a blue flame and a suffocating vapour, and the residue of its combustion is the sulphurous acid: in the language of the phlogistians, brimstone is a compound of two things, sulphurous acid and phlogiston; and, when it is suffered to burn, it gives out its phlogiston or flame of fire, and there remains its dephlogisticated sulphur, or sulphurous acid, in the separated

state. Phosphorus contains, according to the exploded hypothesis, a white deliquescent acid and phlogiston ; and that so loosely united as to be kindled or decomposed by a little friction, or by a slight elevation of its temperature : being burned, it sheds its phlogiston, and the phosphoric acid is reproduced. This school also regarded the metals as compound bodies : each metal was supposed to consist of its own rust or calx and the all-embracing phlogiston : and, when any metal was burnt to a calx in the fire or before the blowpipe, it was considered to have given out its fiery principle, and its ashes or rust remained. Iron was composed of iron-rust and fire, in the scientific hypothesis of those speculators ; dephlogisticate it, that is, burn it to a cinder, and you have the rust. Hence some bodies, such as wood, coal, and especially charcoal, which give out much heat and leave apparently little dephlogisticated matter when burnt, were viewed as substances overcharged with phlogiston, and therefore capable of imparting it largely to others. Now it always was, as it still is, desirable to transform ores, such as the iron-rust in the various iron-stones, into reguline metals, such as iron ; and it has long been understood that the best way of doing so, in the majority of common instances, consists in mingling those ores with carbon in some form or other and then heating them in the furnace ; a thing but too easily explained by the fiction under consideration, for the carbon had only to pour its phlogiston into the ores, and thereby to convert them to metallic natures, solid and bright. In the substance of silver and gold, however, the fire was so compacted and inherent that nothing could take it out of them ; and thence their fixity in the furnace, under all ordinary circumstances : other metals were dephlogisticated or turned to mere calxes, their metallic nature quite gone, when heated to redness

or melted in the air ; but the royal pair remained intact under the fiercest trial, and that constituted their royalty then, as it is one of the conditions of their value now. Even when their calxes were stealthily made by precipitation from the solutions of these noble metals, in the nitric and the nitro-muriatic acids respectively (the strong and the royal waters of a bygone terminology), the least elevation of temperature, even the action of light in some circumstances, or the mere contact of some highly phlogisticated substance, at once enabled them to snatch back their appropriate portions of phlogiston, and thereupon to become silver and gold again.

It might readily have occurred to an ingenuous student of those days to inquire into the fortunes of phlogiston, when once liberated from a metal or a combustible: for, after the combustion of a piece of phosphorus, for example, the phosphoric acid remained; and could be bottled up as a specimen of one of the supposed ingredients of that kind of matter ; but what came of the fiery principle ? where did the flame go to ? was it merely seen for a moment and then lost ? could it not be caught and kept like the acid ? The opinion of the ancients seems to have been, that it ascended right to the empyrean, that boundless space of pure fire, which was supposed to enclose the air as the air enclosed the earth and the water of their universe ; but, in the view of the phlogistians, it was no sooner liberated from a combustible than it passed into combination with the surrounding atmosphere, coming forth from the latent state of combination only to be devoured by the air—born only to die again. It could not, indeed, be emancipated from its union with one body unless another were ready to take it in without delay ; fire was the momentaneous glance of phlogiston in its passage from

one engagement to another ; and thence the necessity of air to common fire, or else of some other atmosphere to the process of combustion in its more exceptional forms. It was therefore in connexion with this way of thinking concerning flame (and respiration at a later period) that Priestley, when he discovered oxygen, one of the constituents of our mingled atmosphere, supposed it to be air deprived of that phlogiston which fireplaces and lungs appeared to be continually pouring into it, and he called it dephlogisticated air.

Among the difficulties which stood in the way of poor phlogiston, there was one which it needed both ingenuity and hardihood to surmount. It had been early observed (especially by Jean Rey, whose name deserves honourable mention as the unwitting herald of Lavoisier) that certain metals were heavier after than before calcification—ten grains or ounces of lead weighed more than ten after having been burned to a calx, whereas they ought to have weighed less, if phlogiston were really a material substance. Lead, supposed a compound body, gave off one of its ingredients, phlogiston, becoming thereby the mere calx of lead ; and yet that calx was heavier than the original lead. Whereupon the friends of phlogiston discovered that it was the one exceptional substance, and possessed of the unique property of positive levity ; so that what body soever it entered into union with, such as lead calx, straightway became lighter than it was before such addition to its substance. Air and smoke had formerly been supposed to be positively light, until Torricelli showed that they rise, not because of their actual levity, but on account of their less density ; and it is curious to consider that the popular mind, as well as the young or half-taught individual intellect, resembles the earlier historic spirit in this

particular, and is invariably prone to the conception of cold, darkness, and other undeniable privatives, as positive things. It is easy to smile at such mistakes now-a-days, with all those accumulated advantages to which the present age has been promoted by the labours of the very men who made them; but it is difficult to realise the position and the attitude of their minds. To do the former requires only a little information and flippancy; while the latter demands knowledge, reverence, and imagination. It would be as ridiculous, as it is impossible, of course, for the investigators of the nineteenth century to go back to the ways of thinking (not to mention the opinions and attainments) in science of the mediæval or the transitional period; but it were desirable to study the circumstances and the psychological direction of the times, together with the particular misconceptions and hypotheses which prevailed in them; for it is probable, if not certain, that similar errors, both in method and in matter, predominate in those departments of our own science, which have not yet lifted themselves entirely out of the limbo of fiction.

This singular evasion of the question of weight, frank and ready as it was, only introduced another perplexity; but the good old chemists were equal to the new emergency. If the calx of lead, or of any other metal, became lighter, in common balance weight, by combining with phlogiston, that subject of a positive levity, how was it that it also became specifically heavier? The calx was a comparatively light sort of stone; the lead, into which it was converted by union with light phlogiston, was a comparatively heavy metal: a cubic inch of the metal was twice as heavy as an inch of the stone. If the particles of an ounce of calx had buoys of fire attached to them, so as at once to change them

into particles of lead, and to make them lighter in the aggregate, how should such enlarged and lightened particles produce a metal of so much greater a specific gravity than the unphlogisticated rust? But there lay the secret; these phlogisticated particles of calx were not enlarged, they were only lightened; the fiery particles were not stuck on the calx ones like so many vesicles; they penetrated them, as a sword goes into a scabbard, and then constricted or compressed them, as the earth draws the atmosphere tight about it, so that a greater number of the fire-pierced earthy particles, thereby rendered metallic, packed into the same space, and therefore the metal was specifically heavier, though absolutely lighter, than the calx from which it was made.

How catholic, elastic, and satisfactory this venerable hypothesis must have been! It was all wrong, indeed, as a substantive doctrine. In one particular, it was a sort of reverse of the truth. It is not the calxes and acids that are simple; it is not the combustibles and metals that are compound; it is exactly the reverse. Sulphur, phosphorus, carbon, and the other combustibles, on the one hand, with lead, iron, and the metals on the other, are elementary; the respective acids and calxes of these principles are the compounds. The phlogistians may therefore be said to have perceived the relation subsisting between these two classes of bodies upside-down, like the figures in a camera obscura; and surely their chamber was obscure enough, all honour to the light they managed to cast into it from the depths of their own minds. The images of things are painted on the nervous receiving-sheet inside the eyeball in the same fashion, namely, in the inverted position; but there is some cunning principle of rectification, whether in or beyond the

retina, whereby those images are put on their feet again before presentation to the perception of the indwelling mind. Now this correcting power was wanting in the intellectual organ of the phlogistic schoolmen; their interior eye had probably not been sufficiently educated to the unsophisticated perception of outward truth by the cruel experience of their predecessors; and they consequently suffered that we might learn not only to look exclusively at nature, but also to see things as they are. Their cogitative energy was still in fact greater than their perceptive capacity, as had been more and more signally the case with their three races of predecessors, the alchemists, the polypharmists, and the physiological school of the ancient Greek movement in philosophy. Nobody who knows anything of Beccher and Stahl, for example, can doubt that they were the equals of Lavoisier and Dalton in all intellectual respects, excepting that Christian virtue of sacrificing the intellect itself on the altar of observation, while they were certainly their superiors in extent of culture and in aspiration. Assuredly this phlogiston of theirs was nothing but an *idolum specûs*, a figure cast upon the imagination from the phosphorescent walls of that cavernous part of the history of chemistry which they were traversing; but it was an image worthy of admiration and reverence. As to the generic idea of it, erroneous though it was and is, it is extant in the science yet; for it is impossible to see wherein that of caloric differs from it as a scientific conception, although elaborated with immensely greater precision, except that caloric is the matter of heat while phlogiston was the matter of fire. Both phlogiston and caloric are substances which have no existence whatever in the external world; they have both been the convenient though fictitious representatives of natural realities,

and they have both been eminently useful in standing for certain phenomena in their several days; but the latter creature of the materialising tendency of unripe science is not a whit better in essence than the former. Then as for the application of the phlogistic dogma to the details of chemistry, that was certainly wide of the mark, yet it glanced by the fact of the case in a remarkable manner; the doctrine was little short of being the half of the actual truth. It kept the calxes together, and the known acids too, as all so many analogons; so that when Lavoisier arrived and discovered the composition of the mercurial calx, the remainder of his task was done to his hand, and all the other rusts and acids followed the oxide of quicksilver by a natural and easy consequence. Moreover, when Davy came on the scene, the classification of our phlogistians, as extended and enhanced by the great discovery grafted on it by the French chemistry, pointed not doubtfully to the alkalis and earths as being probably nothing but the rusts or oxides of metals difficult of separation in the metallic state; whereupon, with the help of electrolysis, he made the brilliant discovery of potassium and the other easily combustible metals. To sum up the whole matter, this phlogiston prepared the way for the balance, just as the balance heralded the Daltonian arithmetic of chemistry. It had done the gigantic task of putting the enormous huddle of known facts into order; and there they stood, awaiting the renovated eye of science in the person of Lavoisier.

It also served as a centre of coherence for the thoughts and new attempts of a race of splendid thinkers and industrious workmen, from Stahl down to Cavendish. But for phlogiston, less than half-truth though it was, the science of these clear-headed and adventurous men

would have been but a crude heap, instead of an intimate and seemingly combination of details; a mingling of all sorts of observations, not a melting of them into one substance; a clumsy puddingstone, or at best a somewhat confused granite, not a clear and many-crystalled quartz; a chaos of the senses, and not a creation of the mind. A great half-truth will be found at the core of the Lavoisierian, at the heart of the Daltonian, chemistries too; for man, at least considered as chemist, is destined to advance by a succession of oblique steps, forward yet ever somewhat aside, for many a time to come; and the sooner he becomes aware of the fact the better. Not till then, at all events, shall he be able to show forth a childlike faith in the past, a manly contentment with the present, and a ripened trust in the future of science and of all generous endeavour. Not till then will he feel the succeeding æons of his vast existence, in every part of history, to be the onflowing of one river, the growing of one tree of life, or the rising as of one human being from infancy to age. The last of these is the truest image, in fact, that could be used. The playful and apparently unsuccessful childhood of chemistry may be said to have passed among those young-souled Greeks, from whom phlogiston came down. They asked such profound questions at Nature that they could not understand her motherly responses, yet the very putting of those questions foreshadowed the whole history of the science. Its busy but little-doing boyhood was spent in the East under caliphs and physicians whose very names are fragrant with romance; its ardent and imaginative pubescence, in the unbroken Christendom of the middle ages, amid the hum of scholasticism and under the shadow of Gothic architecture; and we have just seen something of its sturdy youth of some-

what positive effort during the reign of phlogiston. The fifth of its ages, that of victorious and self-confident manhood, now offers itself to the attention of the historical student; but it will be a relief to the strain of chemical discussion to put in a few words about the men whose names are associated with the memory of the matter of fire, before proceeding to that still more remarkable epoch.

If phlogiston was not formally enunciated, or invented and applied in all its breadth, it was at all events announced in an intelligible manner by Joachim Beccher—a man of an eccentric and keen spirit, a scholar of liberal cultivation, and a wanderer upon the face of the earth. Little that is certain can be said about the particulars of his outward life. He was born at Spire in 1635, was chief doctor to the Electors of Mayence and Bavaria in succession, and subsequently the object of a world of persecution, although under the auspices of the Emperor. One cannot know how much or how little he may have drawn the enmity of his contemporaries upon him by defiance and waywardness; and it is certainly interesting to observe how frequently the Galileos, Harveys, and Hahnemanns of scientific history have been much to blame for the harsh entertainment they have received at the hands of a world, that is as impatient of disdain as it is placable by submission. It is not easy to avoid the suspicion that he must have been but 'a discomfortable cousin' at the best; and perhaps he drew untold comfort and self-reliance from the fact. Be that as it may, he was pursued with the utmost rigour of both the civil and the lynch law of his day, and had to betake himself to flight and expatriation. He fled first to Holland and afterwards to England, but both his travels in exile and his latter end are now lost in obscu-

rity. Dumas avers that the envy of courtiers, and the persecution he everywhere brought on himself by his intolerable vanity, made him the most wretched of men ; but even inordinate self-assertion, still more than overvaliant self-trust, which is easily mistaken by the vain for the insolence of pride, is not without its secret joy, with which no stranger can intermeddle. It is therefore not inconceivable though surprising that, notwithstanding his erratic and peaceless career, he wrote largely on theology, politics, history, philology, mathematics, and chemistry. In one of his chemical pieces, he describes an excellent portable furnace, full of little contrivances, and handy enough in its way ; and it is to be inferred that there was a practical turn in the midst of his multifarious speculative tendencies. He was even more fiercely anti-scholastic than his turbulent predecessor, the raging Paracelsus himself. Standing out for the rights of experiment, he rejected the four elements, as well as the quintessence, fifth element, or first matter of the later alchemists ; but he did so only to promulgate four elements of his own, namely, fire, the earthy principle, the combustible element, and the metallic one. The foundation of his chemical doctrine, in fact, was just a classification of material substances into fiery or imponderable bodies, earths, combustibles, and metals. The latter two kinds of matter being subsequently understood to be analogous in so far as combustibility is concerned, this division was still further simplified. Fire was then the first kind of substance ; earths, calxes, and acids were the second ; and combustibles, including both the metals and the common acid-yielding combustibles, such as brimstone and phosphorus, formed the third : fire, the products of combustion, and combustibles, eventually constituting the logical triad of that chemistry

which arose out of the protest and new classification of this singular reformer; and it is needless to show how true and invaluable all this was, always deducting the materialisation of fire—a thing with which, by the way, the science of this age should kindly sympathise, for it still abounds in materialisations of the same sort. His great work was, let us rather say is, the *Physica Subterranea*, of which only one part remains. It is dedicated to the Almighty Compounder in a strange, familiar, yet striking style, leaving the sympathetic reader in doubt as to whether it is *impious*, or merely *impious*, or actually though fantastically pious. It is true, to be sure, that Van Helmont inscribed his works to Jehovah in a strain which is as devout as it is foreign to the taste, if not to the spirit, of the present day. It were a becoming consecration, indeed, to put upon every grave production; but it ought to be written all over the book, and not only at the beginning or the end; and it should surely be done in invisible and sympathetic lines, so that only the warm and understanding heart of the reader should be able to bring them out on the unostentatious page, and that for no eye but his own.

George Ernest Stahl, the elaborator of the phlogistic hypothesis, was inspired with his thought by the works of this uneasy Beccher. He adored the *Physica Subterranea* more especially. He calls it *Opus sine pari*—a work without a peer; *primum ac princeps*—first and foremost; *liber undique et undique primus*—a book everywhere and everywhere supreme; and so forth. Born at Anspach in 1660, twenty-five years after his master or intellectual sire, he was a physician, and a first-physician to dukes and kings, in Saxe-Weimar and at Berlin, till he died in 1734. His medical as well as his chemical works approve him a man of deep and wide views or

attempts to understand those parts of nature to which he belonged ; and it is well known that he is an important figure in the history of European medicine, while the Homœopathsists of this contentious time of transition claim him as one of the forerunners or outriders of their hierophant. He was born a methodologist, and there lay his strength. His extensive information, gathered from many quarters, grew easily into a system within his mind. By nature and by cultivation he was an unrestrainable system-builder ; and, happily, his method, or principle of unity, was a good one for his sort of studies, especially for the chemistry of that day, which lay waiting for reduction to order after its agitation by the rough-handed Joachim of Spire. There was the particular work to do, here was the very man to do it ; and it was done. Under the influence of poor Paracelsus, as well as of his more immediate exemplar, he was an experimentalist as well as a dogmatist, an advocate for experience as well as for thought, a man of facts as well as of ideas. In short, the theory of chemistry, which has just been explained at some length, was mainly the result of his observative meditation ; and it is unnecessary to add anything to that explanation, until the movement against it under the conduct of Lavoisier comes to be considered.

If Beccher was odd as well as original in his way of thinking, Stahl was certainly original as well as odd in his way of writing. His style is the strangest motley. It is half Latin and half German. This cannot have been owing to ignorance, for he was a learned man, and had more than enough Latin for his purposes. Neither is it to be rashly attributed to indolence or carelessness, for he was an industrious and painstaking chemist and physician. Certes, neither ignorance nor

laziness were amongst his defects. Can it have been the sheer wilfulness of a Titanic and intellectually licentious spirit, like that of his elephantine and sportive countryman Richter in later times? Was there any inward necessity, of a personal and psychological kind, for this fantastic coat of many colours, in which he could not but invest his new thoughts, as seems to be the case of our own Carlyle? Or may it not have been a determined will to introduce, to the extent that he could, the writing of scientific works in the vernacular speech? Let our admiration and gratitude prevail with us to suppose the last of these is the true explanation of this ludicrous characteristic of his, for in that case he would have one claim more on our regard; a claim which should have peculiar force in a popular dissertation like this, for it is clear that science could never have been discussed before the unprofessional reader, until good German and English had been substituted in our books for bad Latin. Since, then, Doctor Stahl may really be considered as one of the tutelary geniuses of scientific literature, the concluding words of his five folios on the *Foundations of Chemistry* cannot be without some interest in the present connexion. It is impossible to exhibit the grotesque effect of the mixture of Latin and German, with a sprinkling of Greek, in a translation; but the impatient etceteras are faithfully taken from the text, and they will convey some impression of the glorious absurdity of the original. The recipe of the folio is this—three parts of good dog-Latin, two of German, one of Etceteras, and a dash of new Greek, to say nothing particular about a pinch of Arabic.

‘As for the use of these things, both for science, that is, the excessive delectation and the cultivation of the mind, and for purposes which are physical, economical,

civil, &c., all that has been said is worthy, &c. :—I advise my noble readers to ruminate over what has been said, &c. But I warn them altogether against those meteoric studies, and vain promisings, opinions, speculations, for fear their mind should ruin their conscience, fame, time, faculty, &c. Wherefore, I warn them away from that vulgarly so-called alchemy and its foolish hopes, for it were surely absurd to hope that God would make a man rich because he has made him wise : and as for doing good with it, that is mere knavery to be spit upon. Our Lord God wishes to have the poor and the rich together, although he could soon make us all rich. Morrhosius, in his epistle concerning transmutation, which is certainly worth reading, for it contains some excellent things, tells how Kelly the Englishman got a certain tincture in a wonderful manner, namely, on condition he should dower poor virgins with it ; but while he toyed with it, and wished to see if he really knew the craft of the thing, he actually wasted it all on trials ; and there happened to him one of those fates, whereof we have no examples now-a-days : wherein is to be seen how their own inconsiderate nature and perversity, especially in youth, can bring men to ruin. Well, truly, does God ever deal with us, even while the divine goodness denies us smiles in order to award us wrath, &c.' So ends the *Fundamenta Chymiae*, and so the world takes its last farewell of alchemy, with the wrath of heaven and an &c. !

In addition to these two patriarchs of the science, it was under the illumination and guidance of this Pillar of Fire that there lived, laboured, and prevailed some of the finest spirits that ever devoted their talents to the work of chemistry. Amongst others, whom the

particular limitations and the general scope of this short paper render it undesirable even to name, there were Scheele of Sweden, Priestley and Cavendish of England, Black and Watt of Scotland, as well as the great Lavoisier himself, at the commencement of his career. To say nothing of the modest and secluded Scheele's discovery of new solid and liquid bodies of every kind, it was these men who began and carried forward that pneumatic chemistry, or chemistry of the gases, which has done so much for the arts of life, which has also been incidental to the transformation of the science, and into which it is now necessary to look, both because it arose among the phlogistians, and because it led to that memorable expansion of modern chemistry about to be described as the epoch of Lavoisier.

It was long till the vital air was clearly understood to be a substance essentially similar to the earth and the sea ; and there is little wonder that it should not, it is so thin, transparent, evanescent, invisible, and mysterious. The result of the earliest thoughts of mankind on the subject, in so far as these are embodied in the young languages of the world, seems always to imply some supposed analogy between the impalpable breath of the physical heavens and the inscrutable spirit of God himself. The winds were *Æolian* powers, or rather potentates, passing through the omnipresent sea of life, now rushing with demoniacal hurry athwart the scene, and now gently stirring it like the breath of angels. The very word 'spirit,' in Hebrew, Greek, and Latin, is significant of breath. It appears that the force of inspiration, or the coming of god or demon into an ecstatic person, is expressed by the word *Wareem*, the winds, in Hindostan ; and the very name cannot but remind one of the divine *Aura* of the ancient Romans, the sacred breeze of

poetic or prophetic rapture. Let facts of this sort be the indications, either that the mind of man in history has ascended step by step from material towards spiritual conceptions; or, contrariwise, that he has come down from a primeval life of ideas into that of nature and the senses, until he has lost the idea in the symbol, and thereby become materialised: there is one conclusion that remains the same in either case, namely, that it was only in comparatively modern times that the truly crass and unreservedly material nature even of atmospheric air, not to mention the other long unknown gases, was plainly recognised. Nor has that aerial ocean, in which we are submerged, ceased to be the inalienable symbol of whatever is spiritual and divine, even now that we know all about it. It is still the appropriate type for the inflowing of the all-pervading Spirit into the private soul of the saint, although its soft and secret substance has been weighed in the balance, solidified in many a tangible compound, and extracted from stones by the hand of art. Notwithstanding all our experiments, fixations and recoveries, it is just as beautiful, as mysterious, and as necessary to life as ever; for science does not destroy the poetical or the spiritual significancy of nature at all; it only removes it to a greater depth. 'Thou canst not tell whence it cometh, nor whither it goeth.'

Galileo was the first to form something like a right conception of the ponderous character of the atmosphere. It had been found, during the erection of certain public works by the then reigning Grand Duke of Tuscany, that water could not be drawn up a pump any higher than some two-and-thirty feet. The piston having been raised toward the upper end of a tall pump, the water followed with due fidelity so far, but it would not move

beyond a certain height. The schoolmen of that day had found an easy explanation of the rise of water in pumps, when the pistons are drawn up, in the famous proposition, or rather figure of speech, that Nature abhors a vacuum :—the air-tight piston being elevated, an empty space is left between the surface of the water and the piston, and therefore the water goes up to fill it, without a sensible instant of delay. But they had now to mend their maxim, because it appeared that Nature did not unreservedly and implacably abhor a vacuum after all ; inasmuch as even water, the very type of mobility and obedience, would not follow the piston an inch above its own particular point of choice ; and they were thereby driven from the ineffectual, but not unpoetical, mysticism of their fathers to something like sophistication, for they were fain to assert that she abhors it only to the height of ten yards or so ! It is never the originators of a great but useful scientific error, nor yet its true and industrious believers, but its indolent perpetuators who will not move to the music of the new fact and the new time, that are ridiculous, shifty, ambiguous, and not respectable.

The case was now put to the discoverer of the satellites of Jupiter, and he seems to have seen into the secret at once. It was reserved, however, for his pupil Torricelli to establish and work out his ready conjecture. The celebrated Pascal repeated, verified, and extended Torricelli's experiments. The truth of the thing, in brief, was and is just this :—air, though comparatively light, is positively heavy, having a weight of its own. The experiments of these men showed that a square-inch column of it, extending from the surface of the earth to the top of the atmosphere, is no less than 15 lbs. in weight. It is this weight of the atmosphere, 15 lbs. on every square

inch, that pushes water into the void left by the updrawn piston of a pump ; and there is, of course, a limit beyond which it cannot push the water, namely, the point of height at which the column of water in the pump-tube is exactly balanced by the weight of the atmosphere. It is just a question of balance ; 15 lbs. can support only 15 lbs.,—a thing which everybody understands now-a-days, thanks to Galileo, Torricelli, and Blaise Pascal—the seer, the discoverer, and the verifier of the fact.

In the time of Van Helmont, who flourished at the beginning of the seventeenth century, the workmen in certain German mines were molested, just as our colliers still are, by poisonous choke-damp and explosive fire-damp ; that is to say (for the words were German, though only too easily domesticated in England), by suffocating and by fiery vapours, the former of which put out life silently but summarily, while the latter might blow its unfortunate victims to pieces. In sarcastic playfulness with the popular superstition respecting these guardians of the mineral treasures of the old earth, that singular man imposed upon them the name of ghosts or gases ; but it must be confessed that he knew little or nothing positive about them. Boyle was probably the first to suspect that some solid bodies do in certain circumstances, when they are heated for instance, throw off artificial airs, resembling the common atmospheric gas in thinness and in elasticity, as well as in dryness and permanency, but differing from it he could not well tell how. It is related of Hoffman, that he got himself into much trouble with the ecclesiastics of his place and time,—who embittered his latter days not a little on account of his physical criticisms,—by averring that the spirits, by whom certain foolish students,

addicted to midnight magical incantations over chaufers glowing within chalk-drawn circles and pentagrams, had been seduced, frightened, floored, otherwise maltreated, and hardly suffered to escape with their lives, were undoubtedly evil spirits or caco-demons, as they had been pronounced by a respectable bench of theological judges,—but the spirit of avarice to begin with, and the spirit of charcoal to carry on the process.

It was young Black, however, the greatest chemist Scotland has produced, and the discoverer of that fact of latent heat which Watt has embodied in the steam-engine, who took the first positively chemical step in this progress. He discovered that limestone (or chalk, or marble, or oystershell), when burned in the kiln, and thereby rendered quick, parts with a kind of air in which no animal can breathe and live; and also that it is owing to its setting free this air or gas that the change from inactive limestone to caustic quicklime is due. He called it fixed air, imprisoned in the rock till the furnace, or oil of vitriol, or the spirit of salt, extricated it from its fixture. He perceived and proved that this fixed air was neither more nor less than of the nature of an acid, but existing, alone of all acids then known, in the airy or gaseous state; not in the liquid or solid one, as was common and world-like. Thus was fairly inaugurated the fertile conception that there may exist many different kinds of airy matter,—just as there are many kinds of solid and liquid substances,—differing as much from the gas of the atmosphere as the vitriolic oil, or the fuming liquor of Libavius, or the essence of turpentine differs from the water of the ocean, or as marble differs from sandstone, and sandstone from alabaster. It was a magnificent discovery, and it was made at Edinburgh almost within the memory of its present inhabitants.

The late venerable Lord Glenlee, who had been the companion of Black, Hutton, Robertson, Adam Smith, and all the intellectual magnates of old Edinburgh, once described to us the sensation it excited amongst the learned of that critical city ; and it must still be avowed that it is the greatest discovery in natural science that has ever been made there. We also remember a conversation with Dr. Chalmers, who retained his generous love of science to the last, concerning this chemistry of the gases. Flinging himself back into the last century, after having condescended on the latest improvements in organic analysis, he exclaimed—‘ Yes, it is all very beautiful ; but think of Black catching fixed air, and discerning it to be an acid, at a time when nobody thought of such things ! that was the great stroke ; it was a very great thing to do.’ Yes, be the orator’s judgment re-echoed now, for it is the first step that is ever the heroic step. It has to be taken in the dark, it has to be taken alone, it can be taken only by a man who is capable of taking all the past along with him, and it cannot be taken by him on whom the bounded present has already crystallized, changing him to a pillar of salt.

Soon after this initiative had been taken by Joseph Black, Priestley invented an easy way of collecting and handling gaseous bodies,—the pneumatic trough with its jars,—and actually came upon some nine kinds of gas (all differing from ordinary air and from one another) in the course of a few busy and even stormy years,—for poor Priestley was as restless a controversialist in theology and philosophy as ever Beccher or any of the alchemists had been, and had to undergo a world of trouble in connexion with his disputatious career. Scheele had meanwhile been making conquests of the same sort in an obscure

Swedish town, with no apparatus but phials and bladders, and had added two or three more to the list of new gases. All Europe followed these sagacious leaders; Cavendish the discoverer of hydrogen, Watt who first suspected water to be composed of two gases, Rutherford the discoverer of nitrogen, Lavoisier the interpreter though not the first discoverer of oxygen, and the rest; until everybody has at length become aware that gases are just the steams of liquids which boil at immensely low points of temperature, these liquids being the liquefactions of solid bodies which melt at temperatures lower still, and that therefore there may be no end to the number of the kinds of gaseous matter, precisely as there is no known limit to the vast variety of liquids and solids. One species, or rather a variable mixture of two or three, composed of carbon and hydrogen, is made in the outskirts of nearly every town now-a-days in enormous quantities, and then sent away from a huge Priestleyan trough and jar, as from a heart, to circulate through a system of metallic arteries for the purpose of lighting the houses of the rich, the chambers of the poor, and the halls of the public, the incredulity of Walter Scott notwithstanding. Hoffman's spirit of charcoal, the fixed air of Black, the carbonic acid of the present nomenclature, is studiously crushed into bottles of soda-water by stout machinery, to be quaffed by the luxurious and the ailing before it has time to fly away. Our cottons and linens are bleached by chlorine. Great balloons are filled with the phlogisticated air or hydrogen of Cavendish, the lightest of corporeal bodies, to carry men of science and fools with singular impartiality. Oxygen and hydrogen are separated from chemical union with one another in water, suffered to remain mechanically mingled, and then made to unite again by combustion at the nozzle of the oxy-hydrogen blow-pipe,

so as to produce a number of useful and beautiful results. The arsenic that may lurk about the putrid remains of a dead and buried man is transformed by an easy process into arseniuretted hydrogen gas, so as by its decomposition to bring the metal that laid him low before the eye of a jury. The spirit of hartshorn is now understood to be but a compound of nitrogen and hydrogen, called ammonia, absorbed by and probably in combination with water ; while the old spirit of salt, or muriatic acid, is just an aqueous solution of hydrochloric gas : and the knowledge of these things is daily made use of in the manufacture of those indispensable liquors. The nitrogen is seduced into something like an unwilling chemical union with the oxygen of the atmosphere, by a device borrowed from nature, so as to yield the nitrate of lime, the nitrate of potassa or saltpetre, the nitrate of soda, and (by a secondary process) the nitric acid or nitrate of water itself, that invaluable oxydant and solvent of the metallurgist and the chemist. Hydrogen, oxygen, nitrogen, and chlorine, the four gaseous elements now known (to say nothing of fluorine, which is doubtless destined to be proved a true gas), and a great number of gaseous compounds of these simple airs with one another, and with both liquid and solid kinds of matter, are not only daily prepared with certainty and precision, but hourly transferred from combination to combination, in the operations of the manufactory and the laboratory. In fact, there is no end to the applications of this pneumatic chemistry, which took its rise within the college of Edinburgh from the mind of a student of medicine, who had been faithfully brought up in the Stahlian creed by Dr. Cullen, at once his preceptor and his disciple. The chemistry of the gases, in truth, is one of several achievements which unite to throw something

like an imaginative lustre around those crowds of nomadic young men, who yearly congregate in the metropolis of Scotland for the study of physic. Within the indefinite circumstances and the questionable appearance of the student of any current session, there may be working and striving towards effective utterance some conception, which will one day raise him to the companionship of the accomplished and much-accomplishing, though mild, retiring, and delicate Joseph Black, who lived as fine a life of science as was ever lived, and died with a cup of milk unspilt in his hand.

But neither the multifarious applications of the pneumatic chemistry, nor yet the light it threw on a multitude of natural operations, was its greatest result. Its relation to the growth of the science was still more important than these things. It was nothing less than a critical momentum in the history of chemistry at large. It rendered the existing theory painfully too narrow; the phlogistic hypothesis and classification could not stretch to its demands; the tree began to burst its bark. That admirable phantom, phlogiston, could not contain, keep in order, and govern all those new discoveries. It was no longer sufficient for its historical purpose. Chemistry was growing too great for its antiquated rule. The very discoveries which would never have been made but for phlogiston, were turning against it almost as soon as they were made. As is ever the case, his own progeny rose up to devour this Saturn; his own dogs wheeled round on this Actæon to rend him; and the memory of Thales and all the Greeks was now to be done to death for more than an age. But the hypothesis stood gallantly at bay; and it is notorious, that the very men whose discoveries brought about all this tendency to mutiny and revolution, stood by the falling order of things to

the last. Neither Cavendish nor Priestley ever abandoned the matter of fire. True to Empedocles and Stahl, they persisted in conceiving of hydrogen as phlogisticated and of oxygen as dephlogisticated air respectively, even after the true constitution of water had been suggested by Watt, discovered by Cavendish himself, and completely interpreted by Lavoisier. Cavendish, indeed, gave over chemical investigation in disgust, and betook himself to electricity, as soon as it became clear that the new theory of chemistry had won the day. The restless and hasty, but inventive and generous Priestley, in his old age, took refuge from his enemies in America, and persevered in the writing of long querulous letters to the Academy at Paris about phlogiston, after it had been taken up by the roots with universal acclamation, and consigned to the Hortus Siccus of history. Old doctrines and beliefs are the true mandrakes, many-rooted in the long-trodden soil; and they utter their cries of pain when they are torn up, like those living plants of old and fabulous renown. Alas! the superlative difficulty, and that not only the intellectual, but even more especially the moral difficulty of loosening the mind from the firm-seeming coast of prescriptive and contemporary theory, and of thereupon tempting the untried deep where no credible land appears to rise, has never been handled with love and justice, whether by poets or historians. More commonly the apostle of the new insults over the senility of the prophet of the old idea; and yet the New Testament might surely have taught Christendom how to think, feel, and speak about every foregoing dispensation. On the other hand, the pain with which an industrious man, whose nature it is to love the past, to revere its great names, to delight in its excellent construction, to cling

to its established ways, to take a paternal pride in his own contributions to its citizenship, and, in fine, to embrace it with all the arms of his soul, must feel the island-home of his thoughts and hopes begin to move under his tread as if it were no island, can be altogether understood only by the high-hearted and adventurous mariner, who has pitched his tent on some pleasant, but volcanic and temporary margin the day before its going down again to the deep. To bring this sad reflection to a merry end, however, it must also be confessed that there is a lazy conservative spirit which is as ridiculous and comic as this earnest passion for the good old ways is tragic and far from ignoble. Perhaps the quaintest instance on record of that indolence, was the case of a worthy professor of chemistry at Aberdeen. He had allowed some years to pass over Davy's brilliant discovery of potassium and its congeneric metals without a word about them in his lectures. At length the learned doctor was concussed by his colleagues on the subject, and he condescended to notice it:—'Both potash and soda are now said to be metallic oxides,' said he; 'the oxides, in fact, of two metals, called potassium and sodium by the discoverer of them, one Davy in London—a verri troublesome person in chemistry.'

It was Antoine Laurent Lavoisier, who first felt the pressure of this necessity for a renovated theory of chemistry, and at once began to construct it, say rather to woo it from the opening bosom of nature, where it lay ready to come forth at the call of him who knew the word of power. Dumas has triumphantly shown that his countryman had formed the idea of his great revolution at the very outset of his career, and that even before many of the pneumatic discoveries of the Swedish and

British phlogistians had been made and published. There can be no manner of doubt, in fact, of the single-handed originality of the French lawgiver of chemistry in bringing about that transition, from the era of phlogiston and the cupel to that of oxygen and the balance, which constitutes the turning-point of the history now under review. It is easy and social to speak with effusion about the division of labour and the grandeur of combination; but it seems generally to be individual men that do the greater business of science and of the world after all. Institutes, academies, royal societies, have all been good; but a man like Lavoisier is better than them all. German, British, American associations have their important purposes to serve, and they subserve them well; but an opinion begins to prevail, that in these days we run some danger of being associated to death. Excessive association certainly tends to the production of weakness in the individual unit, if the resulting whole is strong; and it is fortunate that there are some men so unsocial as to dwell apart, drawing inspiration from the quiet past, from the instant universe itself, and from the whispering dawn that is ever arising in the East.

Strange to say, although Lavoisier was early an academician, there was not a little of this individuality and isolation in his character, notwithstanding that he did not resemble Stahl so much in this respect as Dalton did; but he is never to be compared with these epochal men, his sole co-equals in the history of chemistry, in largeness and energy of intellectual structure, while he may be confidently pronounced their superior in lucidity of the understanding. Born at Paris on the 16th of August in 1743, the son of a rich merchant capable of appreciating his child, he was left very much to the guidance of his own intellectual instincts. Having

studied mathematics, astronomy, botany, all with some degree of particularity, he at length took lessons in chemistry at the hands of old Rouelle, an odd and extravagant enthusiast who professed the science at Paris in those days. A young man of many talents and accomplishments, the world of science lay all before him and invited his devotion. Circumstances conspired with his peculiar genius to lead him into those chemical recesses or *Physica Subterranea* of nature, into which he was one day to shed a whole atmosphere of light. Dumas mentions with honest pride how, while yet a youth of twenty-two, his hero kept himself six weeks in total darkness, in order to intensify the sensibility of his eye to the perception of faint degrees of luminosity ; also how he renounced the solicitations and blandishments of Parisian society for the secluded pursuit of science ; and how he put himself on a dietary of bread and milk, when he found that the want of air and exercise was doing him harm. These are probably things, one might say, which it is more difficult to do in Paris than in London or at Edinburgh, otherwise his countryman and celebrator would scarcely have thought them so notable ; yet they do indicate a spirit of quiet self-determination on the part of the young discoverer. It likewise appears that he soon understood the scope of the great task which began to unfold its proportions before him, and he made ready to undertake it with a deal of cool-bloodedness. Perceiving he should need a good income for his purposes, he busied himself to obtain an appointment as one of the farmers-general of the public revenues. When he succeeded, the chemists said he had forsaken chemistry, and the farmers looked askance upon him as an interloper ; but he eventually approved himself the best of farmers, and the greatest of the chemists of

his day. In timely consolidation of his monetary foundation, he at the same time obtained the hand of the daughter of one of his colleagues in the financial trade, a lady who married Thompson the American, commonly called Count Rumford, after the execution of her immortal Lavoisier.

An academician at twenty-five years of age, he was put at the head of the governmental saltpetre-works at thirty-three, during the ministry of Turgot ; and, after several other little public dignities had been conferred on him, he was made a member of the famous commission on weights and measures in 1790. The year after this he produced his treatise on the territorial wealth of France, and the Constituent Assembly printed it at the expense of the commonwealth. It moreover seems to be the unanimous verdict of his countrymen, at least in these days, that he behaved himself in a manly and business-like way in all his public capacities, such as they were. But within all this busy and successful outward existence there moved an orb of thought and labour, which was of incalculably more importance to the world. The revenue-farmer was working out a vast scheme of chemical discovery and doctrine all the time. Beginning in 1772, his thirtieth year, he had published some forty memoirs in the Transactions of the Academy by 1786, within the space of fifteen years, all of them bearing on his new theory of chemical science. It is also recorded to his honour that, though a rich man, an eminent public character, and a great legislator in science, he engaged in some of the most disgusting of chemical investigations from motives of humanity, thereby adding works of supererogation to those great labours which have given him a name to live for ever in the history of chemistry and human progress. Take him

all in all, he must have been an industrious, devoted, aspiring, public-spirited, virtuous, and really great man ; as he was certainly an accomplished man of science and the first of chemists. As a man of intellect he belonged to his city and his age ; that is to say, he was a positivist, a disciple of Condillac in philosophy—if philosophy it might be called,—a man of the senses and the judgment according to sense, essentially if not formally a materialist, a man of science not a philosopher, analytic and rhetorical rather than a synthetist and a maker, acute not subtle, crystal-clear but not profound. What with his young and demonstrative enthusiasm in pursuit, his intimacy with Laplace and many of the more eminent men of his day, his liberal public spirit, his perspicacious and sceptical mind, his keen but not ungenial criticism of the past, and his discoveries in physical science, it would be difficult to find a more favourable and substantially excellent example of the kind of man and thinker which the eighteenth century could produce, in France and at Paris, than this our lucid Lavoisier. Yet all his services and all his fine qualities could not save him from the revolutionary scaffold. Upon some paltry accusation of their having authorised or winked at the putting of too much water in the Republic's tobacco, a number of the farmers-general were condemned to death ; and the great chemist was one of them. It was in vain that he hid himself in some innermost cabinet of the Academy : he was dragged forth like a skulking malefactor, insulted by a mock-trial, and beheaded with the rest of the suspected publicans. It seems now to aggravate this disgusting scene in the historical eyes of Dumas, but it surely relieves its ignominy in so far as the raging populace were concerned at the time, to think that the guillotine swept off the head, not of the crowned and illustrious Lavoisier,

but of farmer-general Number Five. The truly pathetic circumstance, connected with this homicide, was the fact that the discoverer was just at the middle of his work, as he supposed. These are the last two sentences he ever wrote:—‘This is not the place to enter into any details concerning organized bodies ; indeed, I have purposely avoided that subject, and that is the reason why I have refrained from speaking of the phenomena of respiration, sanguification, and animal heat. I shall return some day soon to these subjects.’ He never returned—in the body ; but his spirit, the clear and unmystifiable spirit with which he questioned the unknown, the candid and obedient spirit wherewith he listened for the answer of nature, is with us still, the nobler portion of the legacy he left with his disciples. May it never leave them ! While the chemists of the rising generation endeavour to assimilate, in their proper personalities, somewhat of the profound insight into principles of the Greek physiologists, the religious industry of Geber and his pharmacologers, the intellectual ambition of Friar Bacon and the alchemists, the inventiveness and method of Stahl and the pneumatic leaders, may they always be strong enough to subordinate those shining qualities to the incorruptible common sense of the great French chemist and his disciples ; and, if still newer intellectual manifestations are now about to be evolved with the development of science, may the same principles of common sense accompany chemistry and its explorers, as the ballast of the good ship, for the name of the slaughtered Lavoisier can never cease to be whispered even on the strangest seas.

It is illustrative of his inborn disposition to cope with the greatest questions, as well as of the power of an old idea in a science, that the earliest spontaneous investiga-

tion of Lavoisier actually drew its initiative from the dogma of Thales concerning water as the first and fontal element of things. That primitive conception, in truth, had never quite disappeared from the horizon of physics ; although water was early reduced to the inferior dignity of being no more than one of four elemental natures, as has been explained above. The fontal or generative character of that all-important liquid had been advanced by Van Helmont in later times in connexion with an especial chemical instance already referred to. That converted alchemist maintained that water was changeable into earth by prolonged boiling, an opinion apparently grounded on experiment, which had the continued countenance of Beccher and Stahl. The transcendental element of the old chemistry, in fact, was long-lived and tenacious. The inordinate love of sublimity and unity was not easily extinguished, even in so methodical a spirit as Stahl himself. He retained a provisional region for facts and thoughts beyond the reach of phlogiston. The belief, or rather the apprehension, of something far more wondrous than metallic calxes and the matter of fire formed the background on which his particular chemical doctrine was painted ; and through the visible darkness of that distance there loomed two or three shadowy figures, pointing inwards to some land of promise. These did not interfere with the foreground, but they made it feel unsatisfactory. They poured a kind of mild and sad contempt upon it. They provoked an undefinable longing in the mind for something they could never give. It therefore behoved the man of a new time, it behoved the young Lavoisier, to lay them to rest in one way or another, to settle the questions they suggested once for all, to discover the limits of chemical inquiry—in one word, to understand without

mistake the boundaries of his sphere ; and happily those lingering ghosts remained in such a questionable shape that he could speak to them. He asked not authority, not reason, not imagination ; for none of these could tell, and he knew it. He asked Nature if water could or could not be turned into stone, and asked in such a way that she could not but accord an intelligible and also an unmistakable answer. He took an alembic, which may be described as an air-tight still, in which the condensed steam or distilled liquor always flows back into the boiler, weighed it, put an ascertained quantity of water into it, made it air-tight, and set the water a-boiling ; the steam rising, getting condensed, and trickling back continually through the tubular arms of the pelican. It was kept boiling in this way for a hundred-and-one nights and days, circulating inside the air-tight apparatus. At the end of that period, the whole had lost no weight. The pelican or alembic had lost seventeen grains. The water had gained weight, and it was muddy with earthy particles. When this muddied water was evaporated to dryness, there remained 20 grains of earth, 17 grains of which had clearly been worn out of the substance of the vessel ; but where had the other three grains come from ? Lavoisier at once assigned them to the incidental errors of experiment, and he does appear to have been wonderfully easily satisfied on the point ; for surely an error of three grains in twenty was too large to be overlooked in an attempt to solve so great and venerable a question. The fact is, that the three odd grains came from the water itself, it, doubtless, originally containing that amount of saline and organic matter in solution. But the experimentalist was right in the main, and the earth, which Van Helmont and Beccher traced to the

transformation of water, was thus discovered to have come from the earthy vessel in which the water had been pertinaciously boiled. Scheele investigated this very question in another manner; he analysed the earth produced, and found it to be the same as the stuff of the apparatus. The experiments of the French and Swedish chemists, taken together, told with fatal effect. The day of scepticism had come at last, for chemistry was growing great enough to fill the imagination without the help of transcendental dogmas, and the new students were merciless experimenters.

The notable circumstance in this experiment of Lavoisier, as has been pointedly urged by Dumas, is the use of the balance. Till this weighing of the alembic, the water, and the residue, the balance had not been used in chemistry as an implement of research; even Scheele had an eye only to the quality, not at all to the quantity, of the earthy matter, when he made his analysis or rather his testing of it. We have already seen how the phlogistians conceived and taught that, when a calx united with a quantity of phlogiston, it had lightness added to it, not weight, and therefore the resultant metal was not so heavy as the original calx. In fact, then, so long as phlogiston, assumed to be the principal agent in chemical operation, was supposed to be even lighter than nothing, the balance could not possibly be introduced into chemistry as an instrument of investigation. Accordingly, when Lavoisier ordered a fine balance to be made with a view to its employment in research, the fate of phlogiston was sealed. The very thought of the balance implied the perception, by him who first thought of it, of the central idea of all positive chemistry, namely, that every chemical operation ends in an equation; if 100 grains, ounces, or pounds of any substance what-

soever are burned, distilled, or in any way altered by a chemical process, then 100 pounds, ounces, or grains of material must be accounted for after the operation ; if 100 grains or hundred-weights of wood are consumed by fire, the 100 must be found, when all is done, in the ashes, the water, and the carbonic acid resulting from the combustion, for nothing is ever lost. Weight was, for this intelligent and resolute stranger on the arena of chemistry, an immutable thing in nature. He saw without a doubt that the opposite of gravity, namely, the levity of schoolmen, was a mere negation ; a relative term, not a positive reality ; a no, not a yes. This original perception, or first act of insight, was the starting-point of his career. It was the first fruit of his happy genius ; and thank Heaven, there were also vouchsafed to him industry, courage, talent, and wealth, sufficient for its fulfilment and elaboration : he had not to teach a day-school, attended by little boys with satchels on their backs, like Dalton during a considerable part of his life ; and therefore he was comparatively rapid in his progress, although he had to work and write during not a few years before he was either listened to or understood—a kind of thing which posterity always likes to forget.

After what has been mentioned, it is easy to understand how Lavoisier should have communicated the following note to the Academy so early as the 1st November 1772, when only in his thirtieth year, before the discovery of oxygen gas, and before the full development of chemical pneumatics, which has been sketched above : —‘ I have lately discovered that where sulphur is burned, there is produced an acid with increase of weight ; and it is the same with phosphorus. That increase of weight comes from the fixation of a prodigious quantity of air.

If the metals also, when calcined, increase in weight, it is just from a similar fixation of air, and I can prove it by experiment. In fact, if I take a metallic calx and heat it with carbon in shut vessels, then at the moment when that calx is reduced to the metallic state,—at the moment, for example, when litharge, the calx of lead, is changed into metallic lead, there reappears the air which had become fixed when the metallic lead had previously been made into a calx, and you may collect an aerial product at least a thousand times more bulky than the solid litharge employed.’ ‘This experiment,’ it is added, ‘appears to me to be one of the most interesting that has been made since Stahl:’ and so indeed it was, for it involved the superseding of the Stahlian view of, and way of looking at, the phenomena of chemistry. This experiment, in truth, clearly contained the discovery that when brimstone and phosphorus are changed by combustion into acids, and when a metal is burned to a calx, the change is owing, not to the giving out of phlogiston by these combustibles respectively, but to their absorption of and chemical combination with large quantities of some ponderable kind of air. But nobody saw its vast importance except the experimentalist himself. So late as 1778, six years after the observation was made known, Macquer had a great load taken off his stomach, to use his own expression in a letter, by finding, after all due ventilation of the matter among his scientific gossips, that phlogiston was far from being in any need of going to the wall yet. Be it repeated once more, with deep and affectionate respect, that it is no easy thing to give over a cherished theory: it is almost as difficult as to discover a new one; and it is only the frivolous and changeable inventor of new-fangled conceits, or the light-hearted minion of every glittering innovator, that refuses

to do homage to the loyal spirit of the honest conservative. We remember with how much tenderness, we had almost said with what a tone of sadness and sense of injury, the late Dr. Hope chid one of the expectant graduates of the college of Edinburgh, on the occasion of the public defence of their medical theses in 1839, for entertaining the undemonstrable Ammonium-view of the constitution of the ammoniacal salts. The venerable professor retained his well-grounded fidelity to good old Ammonia, saying that he had 'hoped it should at least last all his days.'

Lavoisier knew the worth, and anticipated the future value, of his young and yet immature idea; and that was enough. Dumas has called the particular attention of chemists to the fact, accordingly, that although it was in 1772 that his hero began the interchange of preliminary shots, it was not till 1783, eleven years later, and in the course of his forty-first year, that he fairly gave battle to phlogiston. Till that period, says the historian, Lavoisier seemed to have retreated from his position, in the opinion of the superficial. But it was only because he had not yet collected and organised a strong enough array of facts for the defence of his proposition. In truth, after having been eleven years engaged in the working out of his theory, Lavoisier was in the glorious minority of one, in so far as the chemists were concerned: he had only one disciple, and that was his friend Laplace, the astronomer. It was not till 1787, when the reformer was forty-four years of age, and a veteran in science, that Fourcroy began to teach both the phlogiston hypothesis and the oxygen theory in his public lectures, and to draw a comparison between them to the advantage of the latter. Berthollet joined the new cause the same year. Guyton Morveau, Monge, and gradually all the

world, including Great Britain, followed these leaders at last. Then, after everybody was converted to the new views, and after the academicians had aided our discoverer in the construction of a nomenclature fitted for the expression and illustration of the new chemistry, it began to be everywhere discussed and applauded as the doctrine of the French chemists, forsooth! 'This new blow was very painful to him,' writes his admirable vindicator:—'That theory,' he cried, 'is not, as I hear it called, the theory of the French chemists, it is mine own; it is a possession which I claim at the hands of my contemporaries and posterity.' Much was also said, of course, about those things which he owed to Priestley, Cavendish, Scheele. He owed them much; yet he owed them only facts, and facts distorted by the false medium through which their discoverers saw them: facts which never conducted them to any such result, but facts which easily fell into order under his theory, and facts that he discovered for the most part almost as soon as themselves. He owed them not a ray of thought: he owed them obstruction. Nor were good-natured and impartial critics slow to remind a generous cosmopolitan public that Jean Rey (and who knows whom besides?) had previously found that metals were heavier after than before combustion or calcination, and did then contain air; but they reminded neither the world nor themselves that the invaluable discovery remained as barren as ice, until the radiance of Lavoisier's searching spirit made it flow over the plain, bringing all manner of fruits out of the willing earth, and going down to bear rich fleets upon its bosom.

It were impossible, within our limits, to trace the succession of particulars in the progress of Lavoisier's career: suffice it that it was arduous, singlehanded,

and victorious in his own lifetime. The crowning moment was perhaps the following discovery:—Oxygen had been discovered by Priestley and by himself; he had also ascertained that it is the oxygen of the atmospheric air that becomes fixed, or absorbed and combined with, when brimstone is burned or a metal calcined; so that the calx of quicksilver was known to contain at least mercury and oxygen, whatsoever else it might contain. He therefore took a known weight of mercurial rust, and drove the oxygen out of it by heat (for simple heating decomposes that oxide); but did so in such an apparatus as enabled him to catch and retain that oxygen, as well as to preserve the liberated quicksilver also. He next recalcined this same mercury, by means of the same oxygen as had just been expelled from the original calx employed; and he thereby obtained the same weight of the calx of mercury as had been introduced into the apparatus at the beginning of the experiment. This was an express illustration of the fact that the red rust of quicksilver is a compound of nothing ponderable but mercury and oxygen, instead of quicksilver being, as had been so long and loyally believed, a compound of its own calx with the positively light phlogiston. When it was made out that the sum of the weights of the mercury and the oxygen, obtainable by heat from any known weight of mercurial calx, is exactly equal to that weight, the experimental demonstration was complete.

The substance of the Lavoisierian chemistry may be briefly summed up in a few paragraphs, but that without being careful to assign each particular to its author, seeing the central facts and the great vivifying truth of the whole system were Lavoisier's own unmistakable handiwork.

§ 1. Water is not the element of all things, not the

first of material forms, not the beginning of creation. It is not even the best or highest in rank, as Pindar expresses it, of four or any other number of elements. It is not an element at all : it is the resulting unity of two elements in combination, hydrogen and oxygen. It is the rust or calx of hydrogen, as iron-rust is the calx of iron, as the oxide of mercury is the calx of quicksilver : it is the oxide of the gaseous metal hydrogen. It is curious to take notice of the changing fortunes of this sweet blood of nature in the history of chemistry. First the matrix of the whole universe ; then only one of four elements, though the chief of the quaternion ; more latterly looked upon as at least an altogether peculiar and calx-producing principle ; and at last discovered to be itself nothing but a liquid product of combustion, one oxide among many, the mere ash of so much burnt hydrogen, a common compound of two out of a large number of elements. Yet this composition of water was a critical discovery in its day : for some years the whole science revolved around it ; and it is still the typical illustration of the chemistry of analysis and synthesis. James Watt, of the Steam-engine, though not otherwise known in chemistry, was the first to form the conception that water is composed of hydrogen and oxygen, or rather of phlogisticated and dephlogisticated airs (the same things as objects, certainly, but somewhat different in and for the mind) ; and Cavendish, a truly great discoverer of facts in this science, was the first to make the proposition good by unassailable experiments ; but this all-important discovery was surely mystified in the thoughts of both these inventors, by their mistaken adhesion to phlogiston : so that it was the light of Lavoisier's system, after all, that gave its significance to that capital fact. Lavoisier did make the discovery for

himself, it seems ; and certainly he would have made it first, but for the anticipation of Watt and Cavendish ; yet the grand distinction of the French lawgiver is the circumstance that he was bringing about a reformation, developing a vast system, and exemplifying a new method of inquiry, while our countrymen were the conservative seekers of only particular facts. Such appears to be a righteous judgment regarding the several claims of these three investigators in this matter. Since they represent Scotland, England, and France, respectively, it is but natural that a good deal should have been written with some acerbity on all the sides of the question. Lord Brougham, Arago, Dumas, have all broken their lances in trying to settle the rival claims, to say nothing of the kindly effort of one of the relatives of Watt. It is not long, indeed, since a deceased critic of our own mingled in the controversy, investigating and adjudicating on its merits, with the skill of an advocate and the love of a friend, if not with all the impersonality of a judge. The question has likewise been handled more recently, and that with much knowledge and rare acumen, in the *Life* of their name-sire sent forth by the Cavendish Society. On the whole, however, while feeling that all such questions of priority are but poor things, we stand by the opinion already pronounced without misgiving, but also without much concern, for Lavoisier can spare deductions from his estate of fame, which would impair the heritage of either Cavendish or Watt.

As for the air of the atmosphere, the new chemistry found it to be no more an elementary principle of nature than the water of the ocean, but just a mechanical mixture, of some twenty parts of oxygen, and eighty parts of nitrogen or azote, kept habitually moist by a varying ratio of watery vapour, whether visible or invisible.

It also contains some four parts in a thousand of carbonic acid gas, to say nothing of those traces of ammonia, carburetted hydrogen, and what not, more lately discovered in its all-embracing substance. To the earlier Lavoisierian, then, the atmosphere comprised the three gases, hydrogen, oxygen, nitrogen, and the hardest of solid bodies, viz., carbon or the diamond—the four organogens or main products of the decomposition of organised creatures—plants and animals.

On the other hand, earth, the third of the old elemental quartad, is the resultant of the combinations and mixtures and juxtapositions of some seventeen metals (still to speak from the point of view of chemistry before the discoveries of Humphry Davy, the great consummator of the movement of Lavoisier), of six non-metallic bodies or combustibles—three known, viz., carbon, sulphur, phosphorus; and three inferred to exist, viz., the muriatic, fluoric, and boracic radicals, as they were called,—of five earths, of two alkalis, and of the three atmospheric gases. But oxygen was the most important of all these provisional elements or undecomposed bodies. It converted the three known combustibles into acids, it was supposed to have converted the three unknown combustible radicals into the corresponding known acids; it converted the metals into bases or so many sorts of earth or alkali, and it was supposed to be the calcifying principle of the regular earths or alkalis: and, in fine, the compounds of oxygen with other elements, whether known or shrewdly inferred, were perceived to be the most abundant and widely spread of all natural combinations; so that this whole crisis of quick development may well be called the epoch of oxygen and the balance. It was the pneumatic chemistry that prepared the way for it; it was the balance that ushered

it on the scene ; and oxygen is its great result. The discovery of oxygen rendered the balance both applicable and necessary ; the use of the balance put oxygen in its place within the system of nature and of science ; and they can never be put asunder in the memory of the chemist. A glass-covered balance, turning on an edge of adamant, with the antique symbol of the mercurial calx in one scale, and the modern representative of mercury + oxygen in the other, is that *Libra* of the historical Zodiac into which the sun of Chemistry rose, as soon as the star of Lavoisier was fairly in the ascendant.

§ 2. There is no such creature as phlogiston or the matter of fire. When a body, compound or elementary, is burned, it does not give out imaginary levitative phlogiston ; it takes in real gravitative oxygen. Yet Lavoisier, in laying the matter of fire with its positive levity to rest for ever, could not escape from its power over him. Black had discovered the fact of latent heat, and explained his conception of the phenomenon with the help of the hypothesis of caloric or the matter of heat, a substance not monstrously endowed with lightness, indeed, but possessed of no weight whatever, the very ghost of poor phlogiston ! Lavoisier adopted this caloric. When phosphorus burned in vital air with a flame nearly as dazzling as the sun, he knew that it entered with rapidity into chemical union with the oxygen, and he attributed the heat of the flame to the extrication of the imponderable matter of heat or caloric from the phosphorus, and especially from the oxygen, to say nothing of the light of the flame in the present connexion. In short, the Empedoclean matter of fire, or rather the Stahlian phlogiston, supposed to have less than no weight, was just broken up into caloric, the matter of heat, and an analogous matter of light, both supposed to be absolutely

imponderable substances, of a truly material nature, and capable of fixation by certain of the ponderable forms of matter. Founding on a mischievous and purely geometrical abstraction, to the effect that extension is the only essential property of matter, Black and Lavoisier admitted into their system the notion of a kind of matter capable of entering into chemical combination with the indubitable kinds of matter, and yet not only without visibility or palpability or separability, but absolutely without weight, without the tendency to gravitate towards the central body of the earth, without the power to help the rest of the world to draw towards and move round the sun; in a word, without one of the actual common properties of all the known forms of matter, let the mediæval scholastic or the modern geometer call it an essential property or not! Posterity will assuredly regard this as one of the half-truths or metaphysical mystifications at the core of the Lavoisierian chemistry, as it is well known to be by many now-a-days, notwithstanding that our text-books in this highly positive science are still too full of matters of heat, of light, of electricity, of galvanism, of magnetism, and even of unheard-of odyles or ogres, which the genius of Fact might have been expected to have driven beyond the confines of Science for ever, after the discovery of oxygen and the use of the balance.

§ 3. Oxygen was not only the great agent of combustion (by the extrication of its caloric on its energetic union with the ponderable combustibles), but it was also the principal party to a multitude of more peaceable operations. The respiration of animals, the process of vegetation, and many less important natural phenomena, were all found to depend on this constituent of the atmosphere. It was perceived to be incidental to the

growth of organic beings, to their sustenance, and to their decay. What was true then is true still:—oxygen is the mainspring of a vast proportion of all those movements that are constantly going on under the figured face and visible indications of the terrestrial horizon. It is both the builder and the destroyer of the ever-shifting scene around us—at once the finger and the tooth of time.

§ 4. The conception of chemical union received a great, though by no means a full, accession of clearness from the Lavoisierian movement. The word 'affinity,' standing for the force in virtue of which the chemical combination of two or more bodies takes place, was first used by Barchusen and first defined by Boerhaave. The very word, however, shows that even the latter was swayed by the obsolete notion that it is bodies standing in affinity with one another, that is to say, bodies resembling each other, that are the most prone to enter into mutual union. Mercury was fancied to amalgamate so easily with certain of the metals because it is of a like nature with them. In the new chemistry, however, the strongest and most prevalent compounds were those consisting of the most dissimilar ingredients, for example, those of oxygen and the metals. The term Affinity, therefore, began at once to be equivalent with Chemical Attraction, which also began to be understood as a force acting among the invisible particles of matter, just as gravitation exerts itself among the visible masses of creation:—a thing which Newton had seen and said long before the dawn of this, the chemistry of fact. But the Lavoisierians, especially Fourcroy and all who have come after him, went further in this direction than they were, or are yet, warranted by the facts of the science. They inferred, and even explicitly stated, that chemical attrac-

tion or particular affinity displays itself only between the particles of different kinds of matter, for instance, between hydrogen and oxygen, but by no means between one particle and another of hydrogen or of oxygen. They defined chemical affinity, indeed, as nothing else than the attraction of cohesion mutually exerted between differing kinds of matter. The particles of a piece of brimstone hold together, in the piece, by the force of the attraction of cohesion, as it is named ; and the holding together of mercury and oxygen, in the mercurial calx, was attributed to the same force acting between the two different kinds of element, namely, quicksilver and oxygen. Without entering on the discussion of this vital point, we venture to foretell that this will ere long be considered as another error in the very heart of the Lavoisierian chemistry ; and it is an error which the Daltonian movement has not yet done away with.

§ 5. The Lavoisierian definition of the elemental nature was perfect. It was the first clear conception ever attained to and uttered on the subject. This great lawgiver of chemistry become positive, an apt scholar in scientific scepticism, and the admirer of Condillac, defined a chemical element to be nothing more, and nothing less, than a material substance not yet analysable, not yet broken up into simpler forms ; in short, a body not yet decomposed but not therefore indecomponible, to be called simple for the time being, but not necessarily always to remain in the list of elements ; elementary not in an absolute but only in a logical and provisional sense of the term. The metals, the earths, the alkalis, the combustibles, the three gaseous organogens, were therefore all registered as elements for the meantime. Davy decomposed the alkalis and earths, proving them to be the oxides of so many new and unheard-of metals.

The same chemist, certainly the noblest of the disciples and workmen of Lavoisier, found out the true nature of chlorine, and thereby deprived oxygen of the right to its name; for oxygen had been prematurely chronicled as the acid-gendering element, but chlorine was now discovered to be at once a simple body and an engenderer of acids just as truly as oxygen. Iodine, selenium, silicon, titanium, rhodium, and many other substances, equally elementary with oxygen and the old metals, have followed in their turns, and there are now no fewer than some sixty Lavoisierian elements, while there may well be a hundred of them before the century is out. There is no probable limit, in truth, to the number of this species of elementary principle. If the chemist could but dig deeper into the surface of the world he inhabits, or could be licensed to carry his quarrying gear to the moon, or could even lay hold of the smallest of the Junonian asteroids, to say nothing that might be construed into impertinence concerning the diggings of either Jupiter or Venus, what a pile of such simple bodies he might build up! It should never be forgotten that he has hitherto done nothing but scratch the outside of this old Hertha, and that only to the depth of the thickness of this paper-leaf in comparison with a sphere of two feet in diameter. Yes, he has merely raked a little among the outermost ashes of this great globe itself, the hearth of the family of man; and his own body will soon be ashes among ashes, earth in earth, when the spirit that was in him, returned to God who gave it, may well smile at the remembrance of yon dim spot which men call Earth, and at the century of elements he had gathered from all its little heights and hollows. In fact and in brief, then, there may be six hundred of such elements as ours, just as well as sixty;

and almost every year is actually adding a new one to the catalogue. In the meantime, it is to be understood that, from not one of these present sixty, can the hottest furnace seven times heated, the coldest freezing mixture, the strongest and steadiest galvanic pile, the most thunderous of electric batteries, or the most pungent reagent, were it even fluorine or potassium at a white heat, extract anything but itself. Gold yields gold, iron yields iron, hydrogen yields hydrogen, only gold and iron and hydrogen, to all the solicitations of the fiercest analytics yet known. 'We stand before the guarded door of nature: the strong bolts will not move: everything fails us, everything!'

Yet it is hard to think that all those sixty creatures are truly simple or elementary. The instinct of humanity revolts against believing that the Maker has departed from His wonted simplicity of procedure in this one part of creation, and flung such a number of unchangeable elements from His immediate hand. Many thoughtful and ingenuous men, indeed, have frankly supposed that it were more like the nature of the Deity, as shown by His interpreted works, to pour forth the unreckonable variety of things from the bosom of one or two principles. Thales and the Greek physicists, Geber and the polypharmists, Roger Bacon and the alchemists, Stahl and the phlogistians, Lavoisier himself, Humphry Davy, Prout, even Berzelius, that man of multitude, have all given more or less explicit expression to this native yearning of the thoughts of the heart of man towards simplicity, that is to say, towards some unity or other underlying the multiplicity of appearances, in this subterranean domain of nature. Man does not love multiplicity; he admires it; but it is unity that he loves, for it moves his imagination while it touches his

heart, not only making the whole world kin, but also lessening the distance between that world and God. The next great question in chemistry then, say rather the perpetual and the greatest question in the science, is precisely this: What is the interior nature of those elements? From the Lavoisierian point of view, in plain earnest, that is the one question of the age. The science bids us ask, and perhaps nature is ready to answer it: but what shall be done, since no known analytical power can move one of those steadfast natures from its propriety? Let synthesis be tried, if analysis has failed: synthesis has never been tried. Be it observed, too, that it is in the highest degree probable that all the sixty present elements are equidistant from simplicity: they are all equally compound (and equally simple, for that matter), if there be any truth in the unanimous testimony of chemical analogy. Their case is exactly like that of potassa, soda, lime, baryta, strontia, and their congeners, before the discovery of potassium; that is to say, potassa once discovered to be a metallic calx or oxide, all the rest were clearly metallic oxides too, as experiment was not long of showing. In the same way, if the secret of one of those silent and tantalising elements be discovered, the secret of them all is out.

Comte's generalisation of the particulars known regarding the growth of man's idea of nature has already been referred to, and it cannot but be interesting to notice the expression of his law in the history of the theory of fire, that impressive phenomenon which continued to be the central point of chemistry until the later Lavoisierians at length put it in its proper and subordinate place. Common combustion, as brought about by energetic oxidation, will always be an impor-

tant object of study ; but, now that other gases are known to support combustion, now that a pair of solid bodies are easily made to extricate heat and light without the presence of any kind of atmosphere, and now that fire is understood to consist in the production of heat and light by or during any chemical action that is intense enough, the venerable process falls to be considered as an accident, and not an essence. In one word, the Lavoisierian theory of fire, thus widened by the discoveries that have flowed from it, and stripped of the adhesion of caloric, is an illustration of the third epoch of human thought upon the subject, according to the classification of the French positivist ; it is the plain, unsophisticated, positive statement of the facts of the case, as these present themselves to the senses and the judgment according to sense of the true chemist. The second, the metaphysicising or fictitious stage of the theory of fire, is represented by caloric, still more curiously by phlogiston, and also by the ancient element and empyrean ; abstractions of the mind transformed into forbidden creatures, veritable ghosts. And as for the earliest, the religious or superstitious time of knowledge or thought, concerning this fiery manifestation of the powers of nature, not only is the mythological story, how Prometheus snatched the element down from a region of fire* beyond the atmosphere and its thousand stars, an indication of the idolatrous feeling flung around a natural wonder, but the salamander or fire-spirit of the Rosicrucian mystics was a supernatural creation of the theosophic sort, almost belonging to post-mediæval Europe. Fire for the altar, strange fire, fire from heaven, and burnt-offerings, are the common

* The word Empyrean designates, it need scarcely be said, the Place of Fire.

elements of all the antique worships of the world. Fire has also yielded some of the strongest of the imagery of the sacred books of Christianity. In the end, the earth is to be burned up, the very elements are to melt with fervent heat, the heavens are to pass away like a scroll in the flames; while the horrible nature of sin is set forth by that place where the fire is not quenched; and surely the image of ever-burning yet unwasting fire, is a symbol more easily turned into ridicule by the frivolous understanding than exhausted by the serious imagination.*

But the true deification of Fire was that of Zoroaster and the Guebres, those worshippers of the Sun. To them the thing was Divine, the peculiar Shekinah of Jehovah, or the supreme manifestation of God among men upon the earth. The less refining multitude did assuredly, by the million and during long ages of time, look upon the sun as very god of very god; on the moon and stars as his heavenly host; and on the levin-brand, the unrestrainable fire, the culinary hearth, and the household lamp as his flaming ministers. It is difficult now-a-days to realise this devotion—in the presence of a chemical product, a combination of caloric and light, a double vibration, a pair of imponderables, or even a couple of dynamides. The fact is that Christendom has at last got into the extreme opposite point of view to all this worship of nature, and the Beautiful One has been degraded into a drudge, with 'none so poor to do her reverence.' The Briton of the eighteenth and nineteenth centuries actually conceives of the world as an

* To say nothing of Dante and Milton at all in this connexion, if the reader would see how this symbol pierces and informs a Christian poet, let him read *The Devil's Dream* of Thomas Aird.

amazingly complicated, yet exquisitely simple piece of mechanism, put together very much as a watch is made by a watchmaker, and left to go according to law, the great Creator withdrawn to some central heaven, thence beholding all its evolutions, and ready to interfere whenever the gracious purposes of His will require a present Deity. Zoroaster, on the other hand, saw nothing but god and only god in nature; he felt as though god shone upon his eye, almost without a veil, in Fire; and he bowed his head in adoration: while his people, as usual, soon confounded the idol with the divinity, the sign with the idea, and became idolaters.

What a thing fire must have been to the primitive man the first time it flashed upon him! Say that he kept watch over his people; that at the chilliest hour of the night, just before sunrise, he noticed how a dry stick grew warm when rubbed against his club; that he rubbed them again, more stoutly still, and it became hot; at it again, with the wonder of a child and the strength of twenty men, he flung it down for it scorched his hand; yet he could not choose but try again, and it smoked; again and again, quicker and quicker, longer and longer, he pursued the wild experiment until it burst into flame, and the sun arose in the east:—What were the fire upon the brand but the spirit of the blessed sun, come down to dwell with him and his? It is surely not impossible to feel how, in the absence of science, with the presence of only an incalculably small amount of experience, in an intellect far more observative than analytical, and a young soul capable of little more than wonder and love, the worship of the Sun and Fire might arise: and, once risen on a national and continental heart, it could never set until the fulness of a better

time were come. Nor is Christianity herself, the reconciling genius of the world, ashamed to draw upon the memory of that old faith ; for she lifts up her Prince of Peace to the homage of the nations under the image of the Zoroastrian God :—

THE SUN OF RIGHTEOUSNESS WITH HEALING IN HIS
BEAMS.

IV.

SIR HUMPHRY DAVY.

(NORTH BRITISH REVIEW—No. III.)

It will be sixty-six years next seventeenth of December since Humphry Davy was born at the homely and secluded little town of Penzance, among the mines of Cornwall. It is a county of classical antiquity for commerce with the world in its metallic riches. It is streaked with beauty. It spurns the tides of both St. George's and the English Channels with its Plutonic cliffs. The Atlantic is beyond.

His mother, Grace Millett, was left an orphan child, in company with an elder and a younger sister. They were not in want, however; and they were kindly guided by a good man, Tonkin, a surgeon-apothecary of the place, who had lodged with their parents. She was a mild and reflective woman, and, to have done so well by her family, must have been eminently steady of purpose. She had five children, yet never made a favourite of Humphry, her first-born and her stay; and happily she lived to see his honourable labours crowned with success by God and man.

His father Robert was bred in London to the liberal old handicraft of wood-carving. He did not do much work at Penzance, but farmed the little copyhold of

Varfell, some two miles out of the town. He was venturesome upon a small scale, and apt to lose his money. A man of social temper, if not of jovial disposition, Mr. Davy seems to have walked through the world as becomingly as possible. He was short-lived like his son, and died when Humphry was only sixteen.

The name of Davy stands on the old church-tablets of the neighbourhood as that of the proprietors of Varfell, a small estate in Mount's Bay. One of these is so far back in date, indeed, as 1635; but the lineage of Sir Humphry Davy, Baronet, Doctor of Laws, and President of the Royal Society, can be traced no farther up than to his grandfather, a substantial house-builder in the west of Cornwall. The Milletts, too, one of his biographers is careful to tell the enlightened world, were originally 'aristocratic and wealthy;' but alas! their fortunes had so crumbled down as to leave little Grace and her sisters the heirings of a mercery-shop in a place with no more than 2000 inhabitants. Let the Milletts and the Davys, however, have been in ancestry what they may, so small a consideration can never affect the simple fact, that the one Davy whom history cares about was born and bred amid the influences of what may be called the trades-professional sphere of the society composing the most primitive and isolated of English mining towns, and that in somewhat needy and afflictive circumstances. It is more interesting to know that from the Last of the Carvers, as the people of Penzance called his skilful father, he inherited a contriving head and learned hands; while to his gentle mother he owed the temperament and the habits of serious contemplation.

His boyhood was in no way remarkable. He learned his letters quickly; read Æsop's Fables and the Pilgrim's

Progress like other British lads ; preferred the perusal of history books to learning his lessons ; was an idle schoolboy in fact ; used to harangue his companions, as well as tell them stories ; made verses, thunder-powder, and turnip-lanterns ; caught grey mullet at the pier better than his playmates, by the help of a device of his own ; organised and headed troops of puerile soldiers, with pasteboard shields and wooden swords ; and, as he grew bigger, shot birds among the lanes, as well as got up some sort of play for his schoolfellows and himself to act in character. Consequently, there is no wonder that when sent to Cardew's school at Truro, at fourteen years of age, the Doctor ' found him very deficient in the qualifications for the class of his age,' and ' could not discern the faculties by which he was afterwards so distinguished ;' although ' his turn for poetry' was both noticed and encouraged. In a word, living more with old Tonkin than with his parents, the amiable yet wilful boy was, as he long after rejoiced to remember, left very much to himself, was put on no particular plan of study, and enjoyed much idleness : a noble education in those rare conjunctions where affectionate yet indulgent friends, and the simple manners of a country-town, conspire with magnificent and multiform displays of Nature to kindle and unfold a young character, in which the elements are so sweetly tempered as they were in Davy.

Leaving the Truro school at fifteen, he idled, played billiards, fished, fowled, swam, and took lessons in French ; till, two years after, he was apprenticed to a medical practitioner of the name of Borlase. His father having died the year before, he now displayed that determination to succeed which not only never forsook him, but con-

ducted him from victory to victory ; as it did Napoleon, and as it shall lead every man of prowess that is yet to act upon the fortunes of the world. His faithful brother and biographer has recorded a plan of study composed by the future discoverer at this time ; embracing theology natural and revealed, geography, six professional studies, logic, physics, rhetoric and oratory, history, mathematics, and seven languages. This pitch of cultivation he never reached, and never flew ; but how aspiring ! In truth, he was too spontaneous to be a plodder, and had not yet acquired that nobler way of using books which is never learned but by a few. Connected with this was the amazing rapidity with which he would rush through a book from his very boyhood. A youth of sinewy faculty, rather than of craving capacity, he felt the noble necessity of discharging his bursting but imprisoned force in repeated, and still repeated acts of original production. Accordingly, he was for ever writing on religion, describing the arc of declension into solid materialism and of reascension into the more mobile elements of a kind of rational orthodoxy ; on government ; on climate ; on friendship and love ; on the ultimate end of being : and such subjects. He wandered alone by the shore, opugning the all-eloquent sea in order to practise his ambitious oratory : alone he sought and loved all the great and beautiful objects around him, and wooed them too, for his muse was still awake in spite of metaphysics and medicine : and he sat live-long hours alone upon the cliffs of 'Majestic Michael,' dreaming of glory ; the master-passion of his life already asserting her royal prerogative. Then we are told how he fell in love with a young French stranger, and wrote impassioned sonnets

in her praise: and we believe it, love being an almost unfailing element of genius; for genius is nothing but a thorough self-reliant manliness after all, resolute to do and become all that manhood may. Be these fine things about love and genius as they may, however, poor Davy's early passion must have been very transitory. Did we not know that women generally smile upon the fervid, and that Dr. Paris is a gossip, we should say that probably the youthful savant's unheeded and ungainly figure defeated him in the eyes of the fair foreigner, maugre his fine hair, his sparkling eyes, and his eloquence. At all events, his young heart was already on fire for glory; and on he pressed to feed, if not to quench, the avidity of its rage by conquests of another kind. Ambitious of graduating one day in medicine, at Edinburgh, he advanced from his crude but bold disquisitions in metaphysics to professional studies with the same ardour, and speculated there also like a young Titan. About nineteen he began the study of chemistry; after a year of geometry and other branches of mathematics, won from the hand of Time by his own arm. Now commenced his life for the world. He had not been many months studying LAVOISIER's lucid Elements, and, in his self-tuitive way, experimenting with glasses and cups, plates and saucers, tobacco-pipes and bladders, old barometer-tubes and a syringe, when, with the audacity of an eaglet, he surveyed the science from his own point of view; thought he could 'overthrow the French chemistry in half an hour;' and propounded a new theory of heat and light for himself, doing his little best to support it by a series of rude and inapplicable, but ingenious experiments. Then-a-days one could acquire a very complete book-knowledge of chemistry,

as a theory of one part of nature, in a very short space of time. The erroneous theory, devised by Beccher and propounded by STAHL, which referred all chemical phenomena to the agency of an invisible, inseparable, and imaginary substance, called phlogiston, had enough of truth in it (viz., the recognition of the essential resemblance that exists between the natural operations of the rusting and fixation of metals and the burning of bodies, as well as of the analogy in composition of acids, alkalis, earths, and metallic calxes): this doctrine of phlogiston had enough of truth in it to enable Neumann, Pott, and Margraaf; Reaumur, Duhamel, and Macquer; Bergmann and Scheele; Black, Priestley, and Cavendish, to collect a compacted body of well-ascertained and far from ill-arranged observations. These the labours of LAVOISIER and his countrymen Berthollet, Morveau, Monge, and Fourcroy had rendered still more definite and indubitable: and then, to consummate the movement (which the doctrine of STAHL did, let it never be forgotten, in reality originate), those facts had been freed from the spell that had hitherto held them together, in charmed bondage to the idea of the whimsical but magnificent Joachim Beccher, during the space of nearly a hundred years; and had been drawn, as orderly and almost as easily reckoned as the planets, around the central thought of the lucid and organic Lawgiver. Accordingly, all that Davy could find in his *Elementary Treatise** we undertake to describe in a single sentence.

Well, from LAVOISIER he learned that the earth, the water, and the air, with all that they include, are the objects of the chemist's fond investigation: That he

* "Traité Élémentaire de Chimie, présenté dans un ordre nouveau et d'après les découvertes modernes," &c. Par M. Lavoisier, &c. 1789.

inquires into the composition of each of them in particular, in quest of their general law of composition: That the earth is made up of metals and other combustible solids, oxides of metals, acids, alkalis, and earths; the air of three kinds of air, oxygen about 20 parts, and nitrogen about 80 parts in 100, with but a small proportion of carbonic acid in 1000 parts; and the water, of oxygen eight parts, and hydrogen, another kind of air, one part by weight, holding dissolved in its substance varying quantities of such of the soluble ingredients of the earth and the air as have been exposed to its action: That according to the new principle regarding the material elements,—viz., that every substance, not resolved by the skill of the chemist into two or more simpler ones, is for the time being to be counted for an element,—the world in gross is produced by the combinations and mixtures of seventeen metals, from antimony down to zinc; of six non-metallic oxidable bodies, three* known and three† only inferred; of five earths; of two alkalis;‡ of three gases, oxygen, nitrogen, and hydrogen, the first of these being the most important in the actual operations of nature, at least in this planet; and of two imponderable but not inseparable creatures, heat and light, which cannot be procured apart from the substantial forms of matter, either singly or together: That as the mechanical phenomena of the globe, such as the tides, the flow of rivers, the descent of avalanches, the fall of rains, and the sweep of winds, result from changes in place, among the mingled sensible components of creation, produced by the force of gravitation; so the chemical phe-

* Carbon, sulphur, and phosphorus.

† The muriatic, fluoric, and boracic radicals they were called.

‡ Although (2d edition, 1793) Lavoisier does not put them among the elements, on account of their being so obviously compound.

nomena of the same, such as combustion, phosphorescence, lightning, the quickening of the blood of animals by respiration, the vegetation of plants and animals (so far as that is unconnected with a higher force, above chemistry as well as superior to gravitation), the corrosion of metals, the weathering of rocks, putrefaction, fermentation, all sorts of decay and renovation, in short, result from changes in place among the combined insensible ingredients of sensible shapes, that is, among the particles of matter, produced by the force of affinity, a word introduced by Barchusen, and first defined by Boerhaave: That the differences between gravitation and affinity are, first, that the former moves masses, the latter particles of matter; and, secondly, that the former draws and binds all kinds of masses to each other, but the latter only different kinds of particles; so that particles of oxygen do not combine chemically together, nor hydrogen particles together, but oxygen and hydrogen, or, circumstances being favourable, any other two kinds do unite so as to produce a new species of matter—in this instance it is water—possessing none of the specific properties of either of its ingredients: That gravitation operates upon particles precisely as upon masses, that is on all kinds indifferently, so that particles of brimstone gravitate and cling to each other, although they do not chemically combine; and gravitation is then conveniently distinguished by the name of cohesion: That all other bodies are combined with quantities of heat and light, each body with a specific quantity peculiar to itself, so that when one substance, say charcoal, combines with another, say oxygen, and produces a third, in this instance carbonic acid, which cannot hold so much matter of light and heat as were summed up in the charcoal and oxygen that produced it, then the superfluity of heat and

light are given out; in other words, the charcoal burns in the air, or unites rapidly with the oxygen, the two betwixt them setting free and projecting into space the quantity of heat and light that is over and above what is needful to the material composition of carbonic acid: That sulphur, phosphorus, and nitrogen, as well as carbon, produce acids when united with oxygen, so that oxygen is a generator of acids, whence its name; while the metals by union with oxygen produce oxides which greatly resemble the undecomposed alkalis, the earths being intermediate links of analogy, so that oxygen might be a sort of principle of alkalinity also; whence LAVOISIER hinted that the earths should one day be found to be oxides of metallic bases then unknown: That when the process of oxidation is slowly undergone, there is less manifest extrication of heat, but exactly the same quantity of heat for the same quantity of matter oxidised: That in many such instances of slower oxidation there appears no light at all, that is, there is no high combustion, and it was hence inferred by the majority that light is not a substance by itself, but only a form of heat, or even only an effect produced by the rapid motion of quickly-liberated particles of heat, although LAVOISIER retained it in the *Elementary Treatise*, resting, it is to be presumed, on the Newtonian doctrine of light: That the respiration of animals, and many familiar natural alterations, are instances of this kind of slow combustion, and that by this kindly glow of a gentle chemical action of the 'breath of life' upon the 'blood which is the life,' is the animal frame kept alive and warm: And, to conclude at last, that all the experimental and speculative minor consequences which are fairly and authoritatively deducible from these greater propositions, with all their amplifications by succeeding

labourers in new paths of research, shall be the creed of the true chemist now and for ever ! Reader, rest awhile and breathe : and then go round again to the wicket, where you entered the labyrinth from which you have just escaped into the open country and the freer air. It is no Rosamond's bower, indeed ; yet it is a pleasant coil ; and we entreat you to try it thrice, before you either give it over in despair or condemn us for confusion worse confounded.

Such was the definite and orderly science the novice had to study and contemplate, but it did not satisfy his aspiring thought so long as half a year. The sagacious Black's doctrine of the materiality of heat, which bears the same historical relation to the system of LAVOISIER as the speculations of Beccher sustain to that of STAHL, he saw at once, with that keen glance into the deep analogy of nature which was destined to descry the secret art of decomposing the obdurate alkalis and earths, to be not only inconsistent with well-known though neglected facts, but unnecessary for the sufficient explanation of such as certainly appeared to afford it illustration. There is no doubt that he was right in this daring dissent, although he never did much directly to establish a better solution of the problem, having been soon withdrawn from the prosecution of such subtle inquiries by triumphs of another kind. But the strange thing about these youthful speculations is the fact that our voluntary Coryphæus differed as stoutly from the majority concerning the nature of light, and that in a diametrically opposite direction ; for he maintained experimentally and otherwise that light is a chemical substance, which is productive of vision only when its particles are uncombined and in projection. Then during all that happy year, reposing with inexperienced confid-

ence upon his clever though rude and inconclusive experiments, corresponding with the quixotic Dr. Beddoes on the subject, talking and talking over it with Gregory Watt, who had gone to lodge at Mrs. Davy's house in the vain pursuit of health, and encouraged by Davies Gilbert, he wove himself a fantastic theory of the wonder-working functions of this Lucifer of his in the economy of the universe. Among other things he concluded that oxygen, as it exists in the atmosphere, is a compound of real oxygen and the matter of light; that when a taper burns this light is set free, while the wax unites with the actual oxygenous principle of oxygen and melts 'into thin air:' That, when a man inspires, this phosoxygen (such was the name he put upon the ordinary oxygen of the atmosphere) is absorbed by the blood, carried to the brain, and there decomposed into true oxygen and light: And that the light thus liberated within the most intimate recesses of the 'golden bowl,' from which the stream of higher life appeared to permeate the body, is the nervous energy and the proximate cause of sensation, perception, and emotion. Think of the marvellous projector, nineteen summers old, inhaling the radiance of the sun, nourishing his life upon the glory of the world, and rendering it back to the inexhaustible shekinah in the sublimated form of grateful sensations, brave thoughts, and pious contemplations! In sad and sober truth, the enthusiast was then a materialist; and this dazzling vision, which sanctified the divinity of nature to his kindled imagination, was a compromise between his impersonal piety and the eminently practical but brilliant science by which he was taken captive. Old Beddoes was a convert to the dream.

Dr. Beddoes, once an Oxford professor of chemistry, was the most benevolent but least effective of projectors.

Soon after the labours of the pneumatic chemists, Black and Scheele, Priestley and Cavendish, had conducted to the conclusion, once unexpected, that there are many kinds of air, as there are numerous species of liquid and solid matters, the primary relations to animal life of the kinds that are in the atmosphere were discovered. The earliest distinctions in pneumatic chemistry, indeed, were connected with these very relations. Scheele called Priestley's dephlogisticated air by the name of empyreal air, and Condorcet by that of vital air, both of them on account of its necessity to the sustenance of life; and when the associated French chemists gave it the systematic appellation of oxygen, they fixed that of azote upon nitrogen, in order to intimate that it is privately destructive of animal organisation. The poisonous quality of carbonic acid, the chokedamp of the miner; the pungency of ammonia; the acridity of sulphurous and nitrous acids; the insipidity and negative properties of hydrogen, were all known; and it became desirable to investigate the medicinal virtues of these new and subtle agents. The excellent Beddoes, with the help of subscriptions from the Wedgewoods, and a few other amiable knights-errant in the cause of the amelioration of the condition of mankind by the applications of physical science, established the Pneumatic Institution of Bristol for this purpose. Knowing young Davy of Penzance by correspondence, and admiring him, he offered him the situation of director of the laboratory: and the ingenious visionary was thus, ere he completed his twentieth year, launched into the world from the solitudes of Mount's Bay; where, by the kindest secret influences, and without noise of hammer, he had been built up into the buoyant and exulting form we have just admired, 'with sails full set to catch the gale of praise.'

A happy launch it was. At Bristol now; animated by the unfeigned admiration of poor Beddoes; ennobled by the friendship of his beautiful, gracious, and amiable wife; introduced to the companionship of the graceful and melodious Southey; become a darling 'thing of hope,' of more hope than even himself or any other, to the wondrous Coleridge; within easy reach of his first scientific friend, the accomplished Gregory Watt, and of Keir of Birmingham, the relic of another age; in the way of meeting with famous philosophers on a kind of equality of terms; in a well-appointed laboratory at last, and nothing else to do but investigate: what a delicious, and even perilous, change for the gallant explorer! Yet wisely and bravely he held on his course. A few weeks before, with no propitious breeze behind, and no bounding prospect before him, he had written in his solitary note-book—'I have neither riches, nor power, nor birth, to recommend me; yet, if I live, I trust I shall not be of less service to mankind and to my friends than if I had been born with these advantages.'

Accordingly, during the two years he spent in the service of the Pneumatic Institution, he laboured at his ordained calling of discovery like a genuine apostle. First of all, he made some more experiments on heat and light, writing out his opinions on 205 pages of Beddoes' *Contributions* in the shape of essays. The severity of critics conspired with his growing knowledge of irreconcilable facts very soon to emancipate him from his delusions about phosoxygen, and he hastened to publish himself a sceptic with regard to his own doctrine. According to both Paris and Dr. Davy, he was wofully mortified by the arrogance, precipitation, and errors of this maiden work; but we heartily concur with his adoring brother in the opinion that he had little cause,

for it is an eloquent production, and full of that lofty kind of promise which is real performance.

This misadventure told well upon his subsequent labours as a memorable warning. Accordingly his next, or rather his first discovery, was of another order of pretension. He found that the skin or epidermis of the canes, the reeds, and the grasses, is pervaded by a delicate web of flint, which supports their tall and shapely stems like an outer skeleton.

He did not dally, however, with dainty themes. In connexion with the purposes of the Institution, he wished to inhale Priestley's deplogisticated nitrous air, in order to put to the test a foolish conjecture of one Mitchell, an American, that it is a principle of contagion endowed with extraordinary power. In contempt for this vagary, he at once exposed wounds to the action of the gas, and breathed it among common air. It was necessary to invent a method of preparing it in purity and plenty, before the investigation could be brought to a purpose-like conclusion. After a laborious series of trials, he devised the very beautiful one that is now universally employed, viz., the decomposition by heat of the crystals of nitrate of ammonia, which are thereby resolved into watery vapour and the desiderated gas. Under the famous name of nitrous oxide, he minutely examined and recorded its properties for the first time. He then proceeded to breathe it, and, to his rapturous delight, discovered the rapid and delectable intoxication which it produces on the majority of people. He breathed it from bags, and within a box, and always were the effects uncontrollable and sweet on his glowing temperament. In his notebooks he wrote,—‘ I seemed a new being ;’ ‘ I seemed a sublime being newly created ;’ ‘ as if possessed of new organs ;’ and, best of all, this line of beauty, which fills

and satisfies the ear of every genuine bacchanal in these ærial orgies, because it is true,

‘ Yet is my mouth replete with murmuring sound.’

He tried its effect on Mr. Tobin, Mr. Clayfield, Dr. Kinglake, Southey, and Coleridge, with similar results. In no instance did the inhalation do any material harm, although it seemed to revive old rheumatisms in the joints of Kinglake. Not even did any depression follow the extravagant but transitory excitement. In connexion with a kind of homœopathic theory of the art of healing which he cherished at that time, the discoverer was sanguine of its useful application in medicine. It might be the potable gold of Geber, the vivifying quintessence of the elements of Raymond Lully, the water-of-life of Basil Valentine, the elixir of Paracelsus, or at least some purified and attempered supporter of vitality, for its composition was almost identical in ingredients with that of the atmosphere; yet, in spite of this sudden appeal to his imagination, and of his inexperience in the practice of physic, he never for a moment overstepped the modesty of nature, but faithfully recorded its inutility, and pointed out the fallacies attendant on the trial of so strange and novel a medicinal agent. He proceeded to make certain daring experiments on carbonic acid, carburetted hydrogen, nitric oxide, and other poisonous airs, which nearly cost us his invaluable life. After ten months of incessant labour, interrupted only by an elated run, in quest of squandered health, to Cornwall, he published his first considerable work, the *Researches, Chemical and Philosophical, chiefly concerning Nitrous Oxide and its Respiration*, in the summer of 1800.

He did not wear his laurels with content. His passion

for discovery was too irrepressible, and his 'look towards future greatness' had been too blasting for repose. Convinced that 'the most sublime and important part of chemistry (was) yet unknown,' he cast an eager glance at the very penetralia of the science, and devised plans for the decomposition of those bodies which were known to be compound, but had never been forced to yield up their elements, viz., the muriatic, fluoric, and boracic acids, in order that he might grasp those secret radicals which the Lavoisierians had ventured to anticipate. These mistaken devices did ultimately conduct to one of the two greatest achievements in his subsequent career. Meanwhile he more successfully laid hold of the galvanic pile of Volta, which was afterwards to work such wonders in his favoured hands, and communicated five brief accounts of experiments to the pages of Nicholson's Journal, in the six months before his removal to London. Nor is this all that is to be told of his singular activity during the two admirable years he spent at Bristol. He must have read a good deal of science and general literature; but he was for ever writing, for ever projecting—writing magnificats of nature in blank verse—essays on education, luxury, genius, and dreaming—and fragments of metaphysical fiction and desultory notes; and projecting philosophical narratives, romances, and an epic in six books, relating the deliverance of the Israelites under the guidance of Moses. Let us refresh ourselves with a single little extract from the abstract of a Disquisition on Luxury, before we follow the sage of two-and-twenty years to the vortices of London life. It is this:—'Nature and domestic attachments the true sources of happiness. Cosmopolitanism, the love of notoriety (not fame), the love of pleasure, all fatal to the first and strongest feeling of our nature.'

The Royal Institution of Great Britain originated, at the end of last century, between the committee of a London Society for bettering the condition of the Poor, and that well-known soldier of fortune and effective man of practical science, Count Rumford. It was to be supported by the contributions of members ; to bring science into closer contact with the useful arts by committees of research on baking, cooking, and the like ; to shed the light of science among the higher classes by morning lectures : and it had been providentially appointed to become the scene of the next twelve years of Davy's life and labours. On the recommendation of the late accomplished Professor Hope of Edinburgh, Rumford invited Davy, already known to him by reputation, to fill the place of assistant-lecturer on chemistry and director of the laboratory, with the prospect of being soon made professor in the room of ill-used Dr. Garnett.

It is said that Rumford was sadly disappointed when he saw him, so rustic was he in his air. His success as a lecturer, however, was instantaneous. Everything was propitious. The Continent was closed against the aristocracy. The Institution was highly patronized, and it was a novelty. The chemistry of Lavoisier was easy, clear, and captivating, as has been shown. Davy himself was young, simple as a child, yet daring as a man ; with an actual and a strange discovery already under his feet ; a decisive experimentalist ; and glowing with the fervour of a rude native eloquence, which assumed a metropolitan polish with only too much rapidity. His friend Purkis says that the enthusiastic admiration, with which he was hailed, can hardly be imagined now. Not only men of the highest rank, men of science, men of letters, and men of trade ; but women of fashion and blue-stockings, old and young, pressed into the theatre of the Institution, to cover

him with applause. ' Compliments, invitations, and presents, were showered upon him in abundance from all quarters. His acquaintance and society were eagerly sought. At length the Duchess of Gordon set her 'gracious, graceful, graceless grace's' eye upon the prodigy, and it drew him into the charmed circle of fashion, there to shine, and shining burn, and burning waste the exhaustible fund of force that was in his well-knit frame. How he changed in the focus of such unmeasured and ungenial approbation ! At the sound of the plaudits of the brilliant crowds that surrounded him in the spacious lecture-room, he erected his somewhat careless shape; and the will quickly took that neglected possession and conscious command of every muscle of his frame, which is essential to the graceful movements of the human body. His clear outlooking eye, that had hitherto beamed only with intelligence, began to light up his heavier features with an unhidden sense of superiority. His rich light-brown hair glistened amid the incense of the drawing-room. His largish but eloquent mouth was soon accustomed to pronounce with both elegance and precision. In a word, his countenance and figure expanded in the sunshine. It was natural. Habitual emotion, especially of the aspiring kind, is more capable of modifying the form and bearing of a man than one is apt to think. This it is that draws one natural line of demarcation between the many different orders of society, producing the most delicate distinction of varieties in demeanour. Davy is an instance. He went farther than nature led him, it is true ; and ' assumed the garb and manners of a man of fashion.' What another change for the Bristol chemist, and the solitary rhapsodist of Penzance !

Distant ones trembled for his safety, and warned him of his danger. If in peril, however, he was not subdued,

SIR HUMPHRY DAVY.

l in his five-and-twentieth summer he assured his
ellent and unfailing friend, Mr. Poole of Nether
wey, that 'the age of danger had passed away.'
ere are,' says he, 'in the intellectual being of all men,
amount elements, certain habits and passions that
not change. I am a lover of nature, with an ungra-
ed imagination. I shall continue to search for un-
ted charms, for hidden beauties. My real, my waking
stence is amongst the objects of scientific research.'
is confidence in the persistency of genius in general,
d of his own passion for the glory of discovery in par-
lar, was stout, but not overweening.

He was at his place in the laboratory from ten or
ven till three or four, day after day, just as he had
n at Bristol; and the world knows what he accom-
hed there. In preparing his lectures never was a man
extravagantly laborious. Rarely or never spending
evening in his rooms at the Institution, he confined
self entirely the day before each lecture; wrote
and rehearsed with his assistants, experiments and
in order to insure their dexterity and his own
city of delivery. 'He used,' says Dr. Davy, 'at this
tal, to mark the words which required emphasis, and
ly the effect of intonation, often repeating a passage
or three different times to witness the difference of
ct of variation in the voice.' Notwithstanding, how-
r, this theatrical finicism, he was always himself again
ore an audience; nothing being strong enough to
e or repress his native sincerity and earnestness of
d. We have been told, indeed, by one of the greatest
a, and certainly the ablest critic now alive in Britain,
t while he was express and admirable so long as he
ounded scientific details, he would plume himself
out taste, and swell without discrimination, when

he diverged into subjects of general reflection, or rather declamation ; a kind of composition in which he was far-fetched, pompous, and somewhat puerile to the very last. Yet Cavendish and Banks, Coleridge and Southey listened to him with pleasure. Such critics as had no sympathy with a many-gifted nature, that knew another language than that of science, and had the good sense to speak it on occasion, condemned his luxuriance of imagery as incompatible with the matter in hand. Others sneered at the enthusiasm with which he bended and dilated over a beautiful crystal ; incapable of conceiving how much of his dearest history was associated with such tiny forms. Once for all, the discoverer, who is bound to be as precise as a mathematician in defining his terms, as disciplinarian as a general before a fight in deploying his details, and as dry as a chancellor in summing up his evidence for the final deduction, has a right to be a man again, with all his faculties and sensibilities erect within him, when he leaves the definition, the muster, and the decision ; else how shall the apprehension of the manifold, confluent, interweaving, and unspeakable sympathies of nature with the whole heart and mind of man be insinuated into the awaiting soul ? Now that the press has become so good a substitute for the professorial chair as to have produced a Davy without its aid, it were well that there were far more of Davy's style of speaking about nature in the Universities ; for it is only by the conflict and collision of kindled spirit with their unawakened thought and emotion, that young men shall ever be fired with the passion for a life of valorous endeavour, and excited to achievements worthy of their manhood.

Such was Davy's life for some twelve years of as substantial work as was ever done by man of science ;

adorned by a splendid succession of lectures on Chemistry, Chemistry applied to the Arts, Chemistry in connexion with Geology, Agricultural Chemistry, and his own Electro-chemical theory; and relieved by travels into Wales, Ireland, and Scotland, in quest of mineralogical, geological, and agricultural information, as well as of trout and game; for he was both an angler and a sportsman, though he always preferred the rod to the fowling-piece. In 1803, he investigated the process of tanning at the request of the Royal Institution, and produced a corrected theory of the art. He increased his observations on the combinations of nitrogen and oxygen; erected a eudiometer for determining the quantity of oxygen in the air, on the new fact that nitric oxide, condensed by sulphate of iron, imbibes oxygen with more facility and regularity than any other substance; made an analysis of wavellite, a mineral from Devon, finding it to be a hydrate of alumina, or compound of water and the pure matter of clay; and, above all, advanced with unprecedented success in that wonderful career of electro-chemical research, which he had begun at Bristol, and which he never relinquished till he put himself at the head of all the contemporary chemical discoverers of Europe.

It was in 1789 that Galvani observed the startling fact that the leg of a dead frog is convulsed, as if the animal were yet alive, when a piece of metal is made to connect the muscles with the nerve of the limb. So extraordinary a thing fixed the attention of the world, and people thought the principle of life itself was about to be laid bare. Volta at once referred the phenomenon to the electricity developed by the contact of two metals; and, in order to increase by multiplication the amount of force to be elicited in that way, he piled couples

of pieces of copper and zinc one above another, wetted cloth being put between each couple. The original theory of this remarkable instrument was this: that by induction the copper pieces are thrown into a negative-electric condition, and the zinc ones into a positive, so that when the uppermost zinc one is brought into contact, either directly or by the medium of a third body capable of conducting electricity, with the lowest copper one, there takes place a discharge similar to that of a common electrical battery. The restoration of electrical equilibrium, however, is only momentary, on account of the continual new development of force by the continued contact of the metallic pieces; so that the current of a Voltaic circle is made up of an endless series of little electric shocks following each other in swift succession, like the sound-producing vibrations of the air. One hand having been placed on the zinc piece at the top of this Voltaic arrangement, the instant the other hand touches the copper one at the bottom, the arms and chest sustain a convulsive shock, violent in proportion to the size of the pile. The ordinary method of submitting minute objects to the influence of this shock is to attach a free wire to the top and another to the bottom of the instrument. As long as these wires do not come near each other, the galvanism is latent. When their points are approximated so as not to touch, at a particular distance for each apparatus an electric spark passes from point to point: and if the points of the wires be inserted into mercury, water, or any of many other substances called conductors, the conductor in question is submitted to a galvanic shock or current, precisely like the body of one who touches both ends of the pile at once. The effect of this current was eagerly tried upon all sorts of bodies.

In 1800, Nicholson and Carlisle, dipping these two wires into some water, were astonished to observe that oxygen was evolved at the positive, and hydrogen at the negative pole.

Ritter made the same observation, and found that if two glasses of water, connected by a bent tube full of vitriol, be employed one for each wire, the effect is not prevented. He inferred that water is a simple body, which becomes oxygen when combined with positive electricity, and hydrogen when united to an equivalent proportion of negative electricity. These two kinds of electricity are imaginary absurdities invented by Dufay, who called them vitreous and resinous electricities, to render electrical phenomena intelligible. Franklin believed in only one electricity; a body being in a state of positive electricity when possessed by an excess of the fluid, and in a negative condition when deficient of that equipoised amount which he supposed to be necessary to the neutral and quiescent existence of all bodies. On a foundation so unsubstantial as Dubay's figment, did Ritter build his inference.

In 1803, Hisinger and Berzelius of Sweden determined that many compound bodies are resolved into their proximate elements, when a current of galvanism is sent through them in a state of solution; and made the important generalisation that acids invariably gather round the positive, and alkalis appear at the negative, wire of the pile.

So early as 1800, Davy had repeated and varied the experiment of the discoverers of this decomposing force of galvanism; and had constructed, the year after, an apparatus with two liquids and one metal: in imitation of the muscle, nerve, and single metal of Galvani's accidental arrangement. After he arrived in London, and

found himself the possessor of everything his heart could wish to follow this captivating new train of dynamical research, he plunged, with his wonted decision and success, into a laborious and masterly investigation of the whole scope of the subject. The greater part of his victories in this well-fought field are recorded in the Bakerian Lecture, to be found in the *Philosophical Transactions* for 1806, and the fifth volume of his collected works. He had first to clear the ground, which had already become obstructed by certain perplexing observations. When water had been decomposed in glasses and porcelain cups, even when organic connecting matters had been discarded and the water had been distilled, there had always appeared both acid and alkaline matter at the poles. This was distracting, inasmuch as every one believed that Cavendish had demonstrated water to be a compound of oxygen and hydrogen alone. Persuaded that Cavendish was not in error, but not utterly rejecting the possibility of some unexpected decomposition of the substances of oxygen and hydrogen themselves, he calmly proceeded to rid the common experiment of every imaginable source of fallacy, and inexorably disentangled the question of its complications. In glass he traced the alkali to the potash of the vessels ; and he had recourse to agate cups, united by filaments of purified asbestos. In these, too, he found alkali extracted from the stone ; but less and less every succeeding time he used the same agates. This looked like the quick approach of land ; and he employed the same cups again and again, in order to exhaust all the alkaline matter that was in them. But the acid and alkali, though they reached a minimum, never ceased to come, and once more the experimentalist was at sea ; although he had meanwhile observed that the alkalinity of the negative water was diminished by heat. He sub-

stituted little gold cups, and found that the alkaline water in the negative cup lost its alkalinity altogether when heated. It was the volatile alkali, ammonia; and the mystery was all but out.

Distilled water absorbs a portion of nitrogen from the air, and if that portion be diminished by any secret cause of removal, the water compensates itself by withdrawing more nitrogen from the atmosphere. Again, ammonia is composed of nitrogen and hydrogen; and nitric acid of nitrogen and oxygen. Ammonia, then, appeared in the negative gold cup, where hydrogen was being extricated: nitric acid in the positive, where oxygen was in the course of evolution: these resulting from the union of nitrogen, absorbed from without, with hydrogen and oxygen respectively. Finally, he galvanised purest water in cleanest gold in a vacuum, as well as in certain gaseous atmospheres that were free of nitrogen, and the tantalising forms of acidity and alkalinity vanished altogether.

The essential point thus placed at rest, he confirmed the experiments of Hisinger and Berzelius; made a multitude more of his own, on the decomposition of compounds into their known ingredients; found that the insoluble, earthy, and metallic salts yield to the same force; described the important part this agency must play among the masses, strata, and beds of the earth, in the formation of mineral veins and deposits; and, in conclusion, mounted to the sublime proposition that chemical affinity is nothing else than electric energy. Among masses of matter an electro-negative body repels an electro-negative one, but attracts an electro-positive substance; and Davy conceived that a particle of acid attracts and combines with a particle of alkali, the former being electro-negative, and the latter electro-positive. In virtue of the same mutual relation, oxygen, which is

electro-negative, unites with the metals which are electro-positive, and so on. Happily for Davy's fame, however, as a sound reasoner, he states his electro-chemical theory in such general terms that half-a-dozen modifications of it, that is, half-a-dozen electro-chemical views, which all spring from this first generalisation of the relations between electrical disturbance and the decomposition of chemical compounds, have been given to the world since its publication. For example, Berzelius, Ampère, and Faraday differ from each other ; but equally agree with Davy, in their respective statements of the electrical theory of chemical combination. For our own parts, we accept none of them, and are of opinion that one and all mistake the contingent for the essential, while they substitute identity for partial coincidence. Meanwhile the great researches of Faraday have amazingly multiplied the data from which a more comprehensive theory of nature shall eventually be constructed. It shall never be forgotten, however, that as Lavoisier imparted to the world the inductive element of chemistry for all time to come ; and as Dalton has laid down the first principle of statics for that coming era of the science, in which the mathematical element shall be infused into its structure ; so Davy has given the first impulse towards a dynamical theory of combination, composition, and decomposition, in preparation for the time we thus venture to prophesy. It is curious, in connexion with this historical fraternity of Davy with Dalton, that the former did not very speedily embrace the atomic hypothesis even as a theory of definite and equimultiple proportions. Thomson relates how Davy stood out after Wollaston and he had capitulated, and (to their honour be it spoken) contributed their yeoman-service to the cause. He covered it with good-humoured ridicule in the company of Davies Gilbert.

The excellent Gilbert waited on Wollaston to warn him of his folly, but came away himself convinced. Davy yielded to Gilbert.

To return : Davy, ever greater in deed than in abstractive thought, and abler at contriving relentless experiments than at constructing definitions, hastened to apply this great instrument of decomposition to the solution of questions of the greatest practical importance, and of vital significance to the growing science. Remember what a greedy eye he cast at Bristol upon the three bodies which had been recognised to be compound, but had not been analysed, in the system of Lavoisier ; and the avidity with which he had invented stratagems for dragging to light the muriatic, fluoric, and boracic radicals, as they were called. It was next to impossible, however, to apply the taxis to the fluoric and muriatic acids in circumstances calculated to secure success, and we seem now to understand why the boracic one should not yield so readily to the convulsive wrench. But there were other substances, in the elemental scale of the day, evidently not simple bodies, and at the same time incapable of eluding the dexterous and determined manipulation of the indomitable electro-chemist. The alkalis, alkaline earths, and earths are, in fine gradation, so analogous to the metallic oxides, both in chemical and sensible characteristics, that it was not easy to avoid the suspicion that they would one day be found to resemble them in composition. Accordingly, LAVOISIER, in a kind of vain oppugnancy to whom British chemists are too fond of advancing Davy's totally different claims, had distinctly announced the probability of these bodies being bases already saturated with oxygen, in that very *Traité Élémentaire* which initiated his admirable disciple into the wonders of the science.

‘ Il seroit possible à la rigueur que toutes les substances auxquelles nous donnons le nom de terres, ne fussent que des oxides métalliques, irréductibles par les moyens que nous employons.’ *

Again,—‘ Il est à présumer que les terres cesseront bientôt d’être comptées au nombre des substances simples; elles sont les seules de toute cette classe qui n’aient point de tendance à s’unir à l’oxygène, et je suis bien porté à croire que cette indifférence pour l’oxygène, s’il m’est permis de me servir de cette expression, tient à ce qu’elles en sont déjà saturées. Les terres, dans cette manière de voir, seroient des substances simples, peut-être des oxides métalliques oxygénés jusqu’à un certain point.’ †

Once more,—‘ Je n’ai point fait entrer dans ce tableau les alkalis fixés, tels que la potasse et la soude, parce que ces substances sont évidemment composées, quoiqu’on ignore cependant encore la nature des principes qui entrent dans leur combinaison.’ ‡

Consequently, a eulogist in the *Edinburgh Review* is mistaken and unjust, when, in reference to the discovery about to be explained, he says that ‘ no prophetic sagacity had placed it among the probabilities of science.’ Davy knew the conjecture of his master from his earliest youth, and that eye for analogies remoter far than any so obvious as these, so keen, so true, which distinguishes him from all the chemists that have ever yet appeared, at once approved the verisimilitude of the conception.

He commenced the investigation on potash. He dissolved the alkali in water, and employed ‘ the highest electrical power (he) could command,’ ‘ produced by a combination of voltaic batteries,’ ‘ containing 24 plates of copper and zinc of twelve inches square, 100 plates

* *Traité Élémentaire*, tome i. 174.

† Tome i. 195. Seconde Edition, Paris, 1793.

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‡ *Ibid.*

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of six inches, and 150 of four inches square ;' but in vain. Some solid potash, now known to be a compound of true potash and water, was then melted in a platinum spoon. The spoon itself was made the positive pole of the battery ; and while, with the potash it contained, it was kept red-hot in a well-urged flame, the negative wire was dipped into the molten alkali. He says, 'The potash appeared a conductor in a high degree, and, as long as the communication was preserved, a most intense light was exhibited at the negative wire, and a column of flame, which seemed to be owing to the development of combustible matter, arose from the point of contact.' The spoon, with its fused and glowing alkali, was next made the negative pole ; the positive wire was dipped into the potash ; but no 'column of flame' arose at its touch ; only 'a vivid and constant light ;' while, from the inside of the spoon, there rose through the potash 'aëriform globules,' like the bubbles of champagne, which burst into flame the instant they reached the air. This was the first flush of victory ; but these beautiful phenomena were still susceptible of more explanations than one ; and this 'combustible matter' had to be handled and examined by an Englishman, instead of merely flashing like an atomic meteor before the eye of an impotent theorist.

Solid and dry potash is a non-conductor. It requires to be fused, so as to entail the disadvantage of executing a delicate experiment at a high heat. Having found that the alkali, very slightly moistened on the surface by exposure to the atmospheric vapour, becomes a conductor, he placed a small piece upon a disc of platinum connected with the negative side of a 'battery of 250 of six and four in a state of intense activity.' Whenever the positive wire was brought round and its point laid,

like the tip of a magic wand, on the top of the potash, the solid alkali began to fuse at both its points of 'electrisation.' 'There was a violent effervescence at the upper surface; at the lower or negative surface there was no liberation of elastic fluid, but small globules, having a high metallic lustre, and being precisely similar in visible characters to quicksilver, appeared, some of which burst with explosion and bright flame, as soon as they were formed, and others remained, and were merely tarnished, and finally covered by a white film, which formed on their surface.'

This was the sixth of October 1807: how memorable a day!

His assistant relates, that 'he could not contain his joy,' but 'bounded about the room,' in an ecstasy of delight. It was not alone that some paltry potash had been decomposed by his hand into oxygen and a new metallic substance; but the theory of chemistry was justified and enlarged; the decomposition of soda, lime, barytes, strontian, magnesia, and alumina, would soon be forced to follow, as indeed they were; a new reactive power, so potent as to remind him of the universal solvent of the alchemist, was almost within his grasp, with which he might decompose silica and boracic acid, as they were eventually decomposed, if not extricate the muriatic and fluoric radicals; in fine, for the present, the analogy of harmonious nature was magnified, and for the future, might not the very metals, royal ones and all, be compelled, by this pile of Volta, to unroll themselves before the world into thin hydrogenous air, and some one unknown constituent? AND ALL BY HIM! It was a glorious day of prophecy and power.

There was still much to do. It was necessary to procure the new body in larger quantities; to examine its

curious properties and relations ; to render it evident that its origin had no connexion with the platinum apparatus ; to prove that nothing but oxygen resulted along with it from the galvanic action on potash ; to show that potash, and only potash, is reproduced by the combination of the new substance with oxygen : and there were difficulties of no ordinary magnitude in the way. The necessity of moistening the potash gave occasion to some, whose names it is better not to perpetuate, to maintain that the new body was a compound of hydrogen and potash ; while the entry of water into the chemical constitution of potash rendered the first specimens of potassium (for such was the name affixed to the metal) more or less charged with hydrogen. But the labours of the discoverer, and of Gay Lussac, who invented a reactive process for the more abundant preparation of the substance, soon disentangled the matter, and made the natural history of both potassium and the metal of soda, which was discovered by Davy a few days after that of potash, as clear as day.

Potassium is a soft silver-white metal, that melts at 136° , can be distilled at a low red heat, and kindles in the air at the temperature where it begins to vaporise. Klaproth, Dalton, and others objected to its being called a metal, on the score of its levity. The judgment of chemists has, however, been decisive that its other metallic qualities entitle it to the rank claimed for it by its discoverer. There should be an end to all such disputes. The number of the elements is not a formally graduated scale running up and down, but an interwoven piece of work in which there is no transition but by a kind of flow ; although many of the parts are still invisible, and there accordingly appear to be interruptions and divisions to the unexpectant eye. Metal or not metal, in the dry air it

quickly combines with oxygen, and is soon covered with a white rust. This oxide is potassa. Potassa attracts the aqueous vapour of the atmosphere and becomes potash; which draws down more and more moisture, till the original bright bead has become a little pool of alkali dissolved in water. This solution combines rapidly with the carbonic acid of the air, and, if it be subsequently boiled to dryness, there is left the carbonate of potash—the pearl-ash of the housewife.

Potassium is lighter than water. It breaks into flame the moment it touches water or ice. If plunged under water there is no combustion, but hydrogen is discharged with turbulence and resistlessness. These remarkable, but far from anomalous, properties suggested to the teeming mind of the electro-chemist the conjecture that the solid body of the world is composed of potassium and the metals that resemble it; and that volcanic eruptions are produced by the occasional incursion of the waters of the deep, or of the great mountain tanks, on the still domain of these deep-hidden metals. The far greater part of the investigated crust of the earth is certainly composed of such oxidated metals, and the specific gravity of the whole globe is supposed to be less than that of even the rocks; so that it is at least possible that there may be more of sound prediction in this conception than the majority are inclined to think. In the most serio-comical connexion with the memoir of 1806, out of which all these great discoveries arose, the prostrate Dr. Paris exclaims with the naïveté of a boy: “a great poetic genius has said, ‘If Davy had not been the first chemist, he would have been the first poet of his age.’ Upon this question I do not feel myself a competent judge: but where is the modern Esau who would exchange his Bakerian lecture for a poem,

though it should equal in design and execution the *Paradise Lost*?" We should certainly not have alluded to this amusing escapade, but that Davy himself all along cherished the opinion, which is more common than is enthusiasm in their own pursuits among men of science, that the principal, if not the only aim of poetry is to amuse; the function of science, or, as it is more ordinarily misnamed, philosophy, being to instruct mankind. They do not discriminate between knowledge and wisdom; nor know, alas for them! that it is goodness and harmony the poet is sent into the world to teach. Far from enviable, indeed, is he who can rise from the thoughtful study of an original investigation into nature, like this of Davy's, without the thankful, though diffident and tremulous hope, that he is a wiser and a better man for the perusal; but surely the student who finds only amusement and delicious titillation of his sensibilities, in a book of *Iliads*, a *Divina Commedia*, an *Othello*, a *Paradise Lost*, or even a *Dream of Mary* in heaven, has yet to imbibe the primitive and the nobler elements of humanity. Differently from Paris does Coleridge, the true admirer of Davy, and himself a poet, adjudge the relationship of kind between the august fraternity of Milton and that humbler guild of which his gifted friend was at once the ornament and the master: 'If in Shakspeare we find nature idealised into poetry, through the creative power of a profound yet observant meditation, so through the meditative observation of a Davy, a Wollaston, or a Hatchett,

By some connatural force,
Powerful at greatest distance to unite
With secret amity, things of like kind,

we find poetry, as it were, substantiated and realised in nature—yea, nature itself disclosed to us, *geminam istam*

naturam, quæ fit et facit, et creat et creatur, as at once the poet and the poem !*

A word about Davy's own poetry, for there will not be another opportunity, so much is there to say about his natural work. Too much has been made of it by his brother, Paris, Cuvier, and certain anonymous writers; for the reported conversational observations of Southey and Coleridge are negative, and refer only to what in their opinion he might have been in literature, if he had not assumed the warfare for which alone, in our opinion, he was intended and accoutred. Now, in such of his versified effusions as have been published, we are able to descry little humanity beyond the love of glory, and the most ordinary if not inferior attachment to home. Then the writer appears to love even nature solely as nature ministering to discovery; and he imitates her mechanical emotions alone. Not only does he never sob as his mother must have sobbed; but he never sighs, nor heaves, nor pants, nor in fury rages like the sea. For a spontaneous bard, never yet was wight so curbed, so straining to be great, so turgid, and, in one fatal word or two, so artificial and scientific. You listen for the murmur of his natal stream, the Boye, or the wave and hush-again of the ever-haunted woods, or the carol of singing birds, in vain. Follow his devious and eager footsteps to the rugged beach, and his verse will never mew and heavily stagger, as if in pain, like the plovers on the way; nor shriek in the wind like the sea-fowl, that deafen the eaves-dropping air around his dreamy head. Nay, aspiring though he ever was, and confident as a full-fledged falcon in his undazzled strength of sweep and eye, neither in his poetry, nor in any of his prose-poetical fictions on the physical theory of a future

* *The Friend*, Vol. iii., Essay vi.

state, given in the *Consolations in Travel*, does he ever soar towards 'the highest heaven of invention,' bearing the awe-struck reader in sudden triumph to the sky. He lifts himself aloft like a crag, that warms and glitters only in the sun.

' By the orient gleam
Whitening the foam of the blue wave, that breaks
Around his granite feet, but dimly seen,
Majestic Michael rises ; he whose brow
Is crown'd with castles, and whose rocky sides
Are clad with dusky ivy ; he whose base,
Beat by the storm of ages, stands unmoved
Amidst the wreck of things, the change of time.'

In reality, with the temperament and the talents of a considerable poet, he was, from the very beginning of his intellectual career, too forward in the conscious pursuit of acquaintance with the particular parts of nature to be the poet of her secret heart. His was a constant sense of antagonism to creation ; and though it was the antagonism of a brother's love devout, yet it was a brother's, and ever too solicitous of displaying her capabilities and varied resources. Accordingly, his muse was neither an ever-revealing, ever-withdrawing shape of pale celestial beauty, like the Beatrice of Dante ; nor a pulsing form of kindly flesh and blood like the Eve of Milton ; but a hard automaton of brilliant metals, precious stones, and clay, himself her Frankenstein, and the glow in her mimic bosom a chemical combustion.

' Hence, she scorn'd
The narrow laws of custom that control
Her feeble sex. Great in her energies,
She roam'd the fields of Nature, scann'd the laws
That move the ruling atoms, changing still,
Still rising into life. Her eagle eye,
Piercing the blue immensity of space,

Held converse with the lucid sons of Heaven,
The day-stars of creation, or pursued
The dusky planets rolling round the sun,
And drinking in his radiance, light and life.
Such was the maiden !'

No, we do not think Davy was a poet ; these descriptions of St. Michael's cliff and the lady Theora are not poetic ; and it is undeniable that he has not penned a single verse the world does not very 'willingly let die.' His sphere and the proper home of his mind was the laboratory. His work and the proper delight of his heart was discovery. There he never faltered. From his last successful toils he pressed forward to fresh investigations. After several somewhat less satisfactory experiments upon the elemental radical of boracic acid, his next important inquiry was into the relations of chlorine to muriatic acid. This green and pungent air, Scheele discovered in 1774. In consonance with the doctrine of STAHL, he named it dephlogisticated marine acid, and believed it to be a simple body. Berthollet, however, under the influence of the Lavoisierian theory, reversed this correct and simple view of its nature, and did for it exactly what the Stahlians had done for the metals. Chlorine results from the action of muriatic acid upon peroxide of manganese, there being nothing else produced but what was called muriate of the protoxide of that metal ; that is, a part of the oxygen of the peroxide had to be accounted for, and Berthollet inferred that it had combined with the free muriatic acid so as to produce chlorine, or, according to his nomenclature, oxymuriatic acid. Muriatic acid itself, as has already been hinted, was classified by Lavoisier as an oxide of some unknown base, to be named for the time the muriatic radical. Gay Lussac and Thenard published a

notice of some experiments in 1809, which subsequently appeared at length in their *Physico-Chemical Researches*, in which they pointed out that oxymuriatic acid may quite as well be considered a simple body ; but they continued to give the preference to the doctrine of Berthollet. It appeared to be necessary for the integrity of the French theory of Chemistry, that no acid substance should be by any means permitted not to contain oxygen, the acidifying principle of nature ; and Cuvier hints that the physico-chemical researchers dared not run counter to the persuasion of their countrymen. It was accordingly reserved for Davy, with his battery, unshackled thought, and decisive experimentation, to demonstrate that muriatic acid is composed of hydrogen and oxymuriatic acid, instead of muriatic acid and oxygen being the ingredients of oxymuriatic acid : that the green air or chlorine, as he called it, is as elementary a form of matter as oxygen itself : and that, consequently, the theory and terminology of a large department of chemical facts must be completely changed. Berzelius was at first averse to the Davian view, and Murray of Edinburgh waged a puny warfare in favour of that of Berthollet ; but the exposition of the beautiful analogies to chlorine presented by iodine, an indecomposable substance accidentally discovered in 1812 ; and the discovery of bromine, another body of the same order, by Balard in 1826, soon combined to establish the truth. It is interesting to know that the reformer entered on this inquiry in the hope of decomposing oxymuriatic acid, and extracting oxygen from the muriatic ; but he bowed to the authority of nature, though it reversed his expectation.

This achievement has been loudly vaunted, especially by his own countrymen, as a victory over LAVOISIER. It

was no such thing. It made known a multitude of facts, of which that great lawgiver of the science was ignorant; but they arrayed themselves under his theory, as naturally as the particles of a chemical solution do round an enlarging nucleus of crystallisation. LAVOISIER and his followers put the appellation of oxygen upon the dephlogisticated air of Priestley, because it was an ingredient of all the acids the composition of which had been ascertained; and they were bound to infer that the muriatic acid, not then methodically decomposed, contained it too. It was not named oxygen because of any peculiar, inherent, and inseparable relation to the property of acidity; for it was known to be a common and invariable constituent of those metallic oxides, which were recognised to be the proper antitheses in idea to the acids; and, as has been intimated already, LAVOISIER himself descried the probability of its being yet found to be the invariable and common ingredient of the alkalis and earths, the conjecture which Davy has so admirably realised. Every chemist is aware, moreover, that it is not the so-called muriatic, hydriodic, and hydrobromic acids that are the real acids after all (if there be any meaning in the word whatever), but chlorine, iodine, and bromine, the salt-radicals of these compounds. So much did chemists, for one example Dr. Turner, unconsciously feel the force of this, that, when it was found that solutions in water of muriates of the oxides of metals evaporated to dryness leave only compounds of chlorine with the metals,—the hydrogen of the muriatic acid having produced water with the oxygen of the metallic oxide and been dissipated by the heat,—there arose the question whether the chloride of a metal becomes the muriate of its oxide when re-dissolved in water. Thanks to Liebig, and what is called the sulphatoxygen theory

of saline constitution, such aimless considerations are, it is to be hoped, for ever done with. At all events we rejoice, heart and hand, to coincide with the indignant Dumas in the reiterated assertion that LAVOISIER is yet intact: 'They have often told you that the theory of LAVOISIER is modified, is overthrown. It is an error, gentlemen, an error! no, that is not true! LAVOISIER is intact, impenetrable—his armour of steel is nowhere beaten in.*'

By this unrivalled series of practical discoveries, Davy acquired such a reputation for success among his countrymen, that his aid was invoked on every great occasion. In 1812, there took place so dreadful a detonation of fire-damp, within a coal-mine in the north of England, that it destroyed more than a hundred miners at a blow. A committee of the proprietors besought our chemist to provide a method of preparing for such tremendous visitations; AND HE DID IT. Still more is it to his honour that he was himself the means of introducing the safety-lamp into the mines of Hungary, personally overseeing its construction and directing its employment. In truth, none of his victories seems to have afforded him so much heartfelt satisfaction. In reporting this beautiful invention to the Royal Society, he says:—'I shall now conclude. Whatever may be the fate of the speculative part of this inquiry, I have no anxiety as to the practical results, or as to the unimpassioned and permanent judgment of the public on the manner in which they have been developed and communicated; and no fear that an invention for the preservation of human life and the diminution of human misery, will be neglected or forgotten by posterity.' 'I value it,' he used to say with the kindest exultation, 'more than anything I ever did.

* 7th May 1836. Leçons sur la Philosophie Chimique, professées au Collège de France.

It was the result of a great deal of investigation and labour; but if my directions be attended to, it will save the lives of thousands of poor men.' How gladly we should have taken down and put reverently up again the simple mechanism of this exquisite device, if our allotted space had admitted of more particular expatiation; this device which has eluded, with the subtlety of a kindly genie, a sublime and gigantic evil that could not otherwise be braved but with despair; this device which, working like the warning ring of Haround Alraschid has protected a multitude of intrepid workmen from instant destruction; this device which gladdened the philanthropic spirit from which it sprang, 'more than anything (he) ever did!' Posterity will be grateful for these generous words; for

He, who works me good with unmoved face,
Does it but half. He chills me, while he aids,—
My benefactor, not my brother man.

In 1823, the Admiralty requested him to prevent the sea from corroding the copper-sheathing of the British navy; and he hastened to apply those principles of electro-chemical induction, which he had so main a share in bringing to light, and that with complete success, so far as the mere chemical preservation was concerned. Nor can there be any doubt that, but for the endeavour to thwart and disconcert his plans on the part of invidious men, his labours would not have terminated till every incidental objection had been conquered or evaded.

Some years before, he had been engaged in unrolling the manuscripts of Herculaneum; but the conservators at Naples, though they thanked him for his suggestions, soon threw impediments in the way of prosecuting the undertaking. The opportunity, however, was seized of examining the colours used by the ancients, as found on

the walls of Pompeii and Herculaneum, and the results were duly recorded in the *Philosophical Transactions*. It is unnecessary, however, to analyse any or all of these his unceasing, and, as it were, supernumerary labours ; for every European student of chemistry is a student of the works of Davy, and the general reader cannot be supposed to accord enough of interest to the consideration of scientific details, not more deeply related to the progress of human investigation into the theory of nature.

We have not followed his private fortunes further than his union with the Royal Institution, because our interest is always concentrated on the struggle of life, while Davy so early shone in the eye of the world, and was by nature so much more than equal to the kind of researches he undertook, that he needs not be looked back upon as one of those heroic spirits whose whole careers have been, like the lives of Columbus, Galileo, and Kepler, but 'a battle and a march' from end to end. Honours were showered upon him. A Fellow of the Royal Society at five-and-twenty, he was elected a secretary at twenty-nine. For his Bakerian lecture he received Napoleon's prize for the advancement of galvanic researches from the French Institute, at a time when national hostilities were at their height. In his three-and-thirtieth year, Trinity College, Dublin, created him a Doctor of Laws, and the year after this academical distinction, he received what is called the honour of knighthood from the hand of George IV., who had just entered on his regency. He was proud of it, because it had been worn by Newton. A day or two thereafter, having first resigned his professorship in the Institution, he married Mrs. Appreece, the rich widow of a diplomatist ; a lady remarkable for intelligence and activity of mind. A few years later, the invention of the safety-lamp brought

him the public gratitude of the united colliers of Whitehaven, of the coal proprietors of the north of England, of the grand jury of Durham, of the Chamber of Commerce at Mons, of the coal-miners of Flanders, and above all, of the coal-owners of the Wear and the Tyne, who presented him (it was his own choice) with a dinner service of plate, worth £2500. On the same occasion, Alexander, the Emperor of all the Russias, sent him a vase with a letter of commendation; and the Royal Society of his own country bestowed on him their biennial medal. In 1817, he was elected to the dignity of an associate of the Institute of France. Next year, at the age of forty, he was created a baronet; but he was never so happy as to produce an heir to the title. At length, in 1820, he was elevated by a large majority to the Presidency of the Royal Society of London, an honorary and laborious office, which he filled, with somewhat more pomp and pride than was either necessary or becoming, till he resigned it in 1827.

Out of a life of so many labours and so many honours few men could have contrived to distil so many pleasures. Fond of travel, geology, and sport, he seems to have visited, for the purposes of mineralogy and the angle, almost every county of England and Wales. In the summer of 1804, when little more than the brilliant Professor at the Royal Institution of Great Britain, he was in Scotland and among the Western Islands. The following season he made a descent on the north of Ireland, for the purpose of examining the basaltic formations of the coast. In 1806, he was again in Ireland, from June to October. Six years after this he undertook a tour of pleasure in Scotland with Lady Davy after their marriage, leaving London in July, purposing to return in December, but getting back by the end of October.

He was provided with a portable laboratory, that he might experiment when he chose, as well as fish and shoot, 'which he almost as much delighted in,' according to the testimony of Dr. Davy. In November of the same year he was at Tunbridge, and there his eye was damaged by an experiment on the explosive chloride of nitrogen. The following year, 1813, he obtained permission from the French government to visit the continent; left London in October, and spent two months in Paris, where he was received with signal politeness and *éclat*, forming the acquaintance of almost every remarkable person in that concentrated metropolis. Proceeding to Rome, Naples, and Milan, where he saw Volta, the godsire of his principal discoveries, he went round to Geneva and resided there from June till September, when he returned to winter at Rome; and next spring, returning through part of Germany, he reached London again in April 1815. Between this date and the same month in 1818, he made several journeys to the north of England and Scotland, partly in connexion with his inquiries into the chemistry and natural history of fire-damp, but chiefly, it would appear, for the sake of his favourite sports. In one of his Scottish runs he went to Orkney. In May 1818, he proceeded a second time to the Continent, visiting Austrian Flanders, Germany, Austria, Hungary, Illyria, Carinthia, Carniola, Istria, and reaching Rome in October, whence he soon hastened to Naples, in order to unroll the Herculanæan manuscripts. After residing at the baths of Lucca and elsewhere, he was once more in England in the June of 1820; and away to the lowland Scottish moors in ever welcome August. It was this autumn he visited Sir Walter Scott at Abbotsford, and wetted his line in the Tweed. Having become the president of the Royal

Society in November 1820, as soon as the duties of the session were over, he betook himself to Ireland, he says himself, for sport in the Bush and the Bahn ; and then to the west of Scotland, it is presumed, for grouse. At last, in winter he found himself once more at Mount's Bay, the scene of his boyhood, and wrote to Poole, 'An uncontrollable necessity has brought me here.' At Penzance they received our baronet and president with every public honour. He stayed a week and more among them. Next summer and autumn away again to fish and shoot among the distant Highlands of Scotland ; his wife not appearing to have accompanied him very much in his travels after their return from their first residence upon the Continent. The following season he went to Ireland and Scotland with Wollaston, whom he seems to have infected with as fond a love of angling as his own. In the summer of 1824 he coasted Norway, and travelled in Sweden, Denmark, Holstein, and Hanover ; visiting crown princes and philosophers ; fishing in strange northern lakes and rivers ; shooting snipes ; eating capital dinners, every atom of more than one of which is registered by him, and published by his brother with becoming enthusiasm and gratitude ; and storing up, for the use of his friends and the British public at large, certain culinary hints concerning cucumbers and the roasting of fowls with parsley in their bellies. The wines they gave him to drink in those ungenial but hospitable climes were good ! Yes, the baronet had a taste in wines ; the president was a gourmet. It was a safer and even a more aristocratic way of escape than almost any other for that superfluous steam of animality which is indeed an inferior, but yet a very frequent excess in the constitution of the man of prowess. Almost every great man is a voluptuary

by nature. Your true consumers of tobacco, your genuine gourmets, your consummate lovers of wine, your most absolute of gallants, and your only sufferable opium-eaters are such men of genius as really do toil like heroes when they are at work. Doubtless, men of genius are endued with the most sensitive and quivering of corporeal frames ; and, if their characters be at the same time strong and vigorous, that swiftly responsive constitution to the play of every sensuous delight is invariably accompanied by the fiercest manifestations of turbulent human passion ; and these are the chief ingredients of the less brutish man of vice. Then there is as little doubt that the alternation of activity among all the elements, which constitute a man complete, furnishes the best conditions for the full activity of each of them in succession. The mind, which is overstrained, instinctively seeks and finds its natural repose in the pleasures of sensation ; and the wearied sense aspires to hide itself in the kindlier bosom of emotion, whence the intellect springs up anew in renovated strength. Happily for the world, the great leaders of its spiritual history have been for the most part men of principle and wisdom, who have known the blessed art of guiding these irrepressible outbursts of their earth-born characters into the beautiful and fertilising channels of virtue. Happy the man of capacious intensity who, in the midst of temptations like those that surrounded Davy from first to last, succeeds in living so well as never once to call a blush upon the face of purity ; for such an one can well afford to tolerate the smile of affectionate criticism regarding the pleasures of the table. But happier he whom, with the highest work to do, and ability to do it in the highest spirit, Providence early withdraws from the fascinations of the world into some

sweet and solemn seclusion, where,—away from both the promotions and hindrances of such inconstant men as easily extol and straightway too easily fall into censure ; in the exhilarating and wholesome company of a quiet few, who love him for the heart that warms his unwearied brain ; surrounded only by the simplest pleasures, and these the lawful dalliances of his human nature ; and interrupted only by the weekly sabbath of creation,—he may spend his unambitious days in the serener toils of investigation, destined not only to enrich but to ennoble the general mind of humanity for every century to come, long after his indifferent name shall have become more than mythic, or even be pronounced at all : as the continental river, covering many a gorgeous plain with wealth and beauty as it rolls its waters to the ocean whence they originally arose, owes its sources to the homely solitudes of some mountain range. Not unlike this ideal would have been the even tenor of time-honoured DALTON, had he not been held to the ground in the cold gripe of poverty almost all his generous days. Amid influences somewhat like these did Bacon end his busy years, and execute his full-orbed works on methodology ; having, by the light that shone inextinguishably within him, transformed the rural prison-home, to which he was banished by the sapient king of Great Britain and Ireland, into a true and long-resounding oracle of the omniscient God of nature. Similar were the propitious fortunes that followed the remote and indefatigable footsteps of Herschel ; all honour to the considerate bounty of George the Third. But above all, not far from such was the sainted life of Newton, awful shade !

Sir Humphry had soon to undertake travels of a more sacred character, and of the most momentous consequences to himself and the world. ‘Whatever burns

consumes . . . ashes remain.' From the period of his excellent mother's death, in September 1826, his vigour had declined. Pain and numbness invaded his right limbs, and his strong heart began to flutter. His last oration before the Royal Society was delivered on St. Andrew's day in 1826, with painful exertion, as if he were about to be stricken down by apoplexy. The skill of his friend Dr. Babington did little for him ; but he rallied, and early in 1827 he was able to withdraw to the Continent from the toils and annoyances of office. It was an inclement season ; but he arrived at Ravenna by the 20th of February, where an accomplished young vice-legate did all 'he could have done for a brother.' 'I have chosen this spot of the declining empire of Rome,' he wrote, 'as one of solitude and repose. . . . I ride in the pine forest, which is the most magnificent in Europe. . . The pine wood partly covers the spot where the Roman fleet once rode. Such is the change of time !' Here his brother, who had attended, left him. He was as diligent as his strength would permit in taking exercise on horseback, among the avenues of Pineta and the marshes of La Classe, with his gun and his dogs ; amused himself by reading ; penned *Hints and Experiments in Physical Science*, for he experimented to the very last ; wrote reflections on life, full of experience, both in verse and prose ; and engaged his powerful mind with contemplations of a higher order still.

We cannot follow him closely in the weary track that eventually led this conqueror of the elements out of nature, the subject and the sphere of all his victories. It was a sore struggle. Throughout his journals there are scattered exclamations of *valde miserabilis*. Poor Davy ! with none but servile hands to tend him ; no one to lean upon in the hour of weakness ; homeless

and alone ; he wandered bravely on in voluntary pilgrimage to shrine of sequestered beauty after shrine, avoiding the interference of physicians, taking counsel of his own heart, and sporting like a naturalist when he could, from April to October : when he returned to London, the arena of his glory, for the last time, ' neither decidedly better nor worse.' Unfit for the excitements and the cares of society, as well as for the active labours of research, he wished to buy some warm-lying, beautiful estate, happily situated for the rural sports he followed with unabated zeal. There, gazing with a fond proprietary sense upon the landscape, watching the weather and the varying year with the eye of a genuine naturalist, deceiving the finny people with the quaint solicitude of another Walton, and looking back with triumphant sighs upon his career,—his life would have oozed away. It was not to be so. His wishes were not met ; his health would not improve ; and he longed for his South Austrian solitudes again. Bidding farewell to London at the end of March the following spring, he spent the summer as he had spent the last ; and then withdrew from the sublime Styrian haunts, which he loved so truly, to reside once more in Rome.

In this premature winter of the year of his life the Discoverer turned for solace, with the trusting love of a child, to the summery bosom of nature. ' Nature never deceives us,' is his plaint. ' The rocks, the mountains, the streams, always speak the same language. . . . Her fruits are all balmy, bright and sweet ; she affords none of these blighted ones so common in the life of man, and so like the fabled apples of the Dead Sea, fresh and beautiful to the sight, but, when tasted, full of bitterness and ashes.' Davy too, the brilliant and successful, had been encountered by disappointment, the entailed

inheritance of human nature. His whole life was calculated to work him up to an exorbitant pitch of expectation. He was never very well fitted by nature, and totally unfitted by experience, for misfortunes. It is well for the world that his early path was easy and open, for success and applause were the necessary stimulus of so sanguine and sympathetic a being. Accordingly, when, after all he had done and enjoyed, they endeavoured to rob him of the dearer honour of his invention of the Safety-Lamp by a base and ignorant cabal, fomented by men whom, now that the question is for ever put contemptuously at rest, it were too much honour ever to name again, there is no wonder that he was deeply wounded by the insult. Then the impediments that were thrown in the way of the thorough investigation of the copper-sheathing question by certain underlings of office, for the weightiest and most selfish of purposes, and the taunts that were invidiously bandied about concerning the apparent failure of his admirable plan for protection, vexed and filled him with just indignation. We men are cruel usurers; for if a man, making himself over to us for better for worse, half-accomplish a difficult discovery in our behoof, we immediately hoot him for his unneighbourly bravery in attacking so impregnable a stronghold, and persecute him into solitude, because his victory is not complete: and so we abandon him to complete it by himself! Not that this of Davy's, vexatious though it was, is an instance very strongly in point; yet it serves for illustration, while it must have stung a man of his unfailing resources and invariable success to the very quick. Nor was Sir Humphry happy in his elevation to the chair of the Royal Society; except in the profaned consideration that it was once the Chair of NEWTON—profaned by the unavoidable remembrance

of the intermediate nonentities that had occupied the sacred seat. We are incompetent to the discussion of this question ; but it is clear that his administration was far from giving satisfaction. The responsibility of every disagreeable thing that transpired in the private transactions of the Society was thrown on him. He was annoyed by a hundred impertinent trifles. Above all, he was disappointed in his life-long hope of one day moving the Government of Britain to patronise the cause of science. Things did not go so sweetly with him as they did in the rising and ascent of his climbing sun. Other sorrows he may have suffered ; others he did, although we cannot well say what. But to a spirit of such inexhaustible activity, it was sorrow enough to feel that cold and relentless hand of palsy creeping slowly over him ; the palm upon his heart, and the chilly fingers over his limbs, to do him leisurely to death.

It was at Rome, on the 20th of February, when he was finishing the *Last Days of a Philosopher*, that he received the final warning to prepare. By dictation he wrote to his brother, who was at Malta with the British troops : ‘ I am dying from a severe attack of palsy, which has seized the whole of the body, with the exception of the intellectual organ. . . . I shall leave my bones in the Eternal City.’ But he was to die neither then nor there. Within three weeks his brother was by his bedside ; and found him as much interested in the anatomy and electricity of the torpedo as ever, though he bade Dr. Davy ‘ not be grieved ’ by his approaching dissolution. Yet after a day of 150 pulse-beats, and only five breathings, in a minute, and of the most distressing particular symptoms, he again revived. Shortly after this, Lady Davy arrived at Rome from England, with a copy of the second edition of *Salmonia*, which he received with

peculiar pleasure. After some weeks of melancholy dalliance with the balmy spring air of the Campagna, the Albula Lake, the hills of Tivoli, and the banks of the Tiber, they travelled quietly round by Florence, Genoa, Turin, slowly threading the flowery sweet-scented Alpine valleys, to Geneva, where he suddenly expired. It was three hours before midnight: his servant called his brother: his brother was in time to close his eyes. It was the 29th of May in 1829.

They buried him at Geneva. In truth Geneva buried him herself, with serious and respectful ceremonial. A simple monument stands at the head of the hospitable grave. There is a tablet to his memory on the walls of Westminster Abbey. There is a monument at Penzance. His public services of plate, his imperial vases, his foreign prizes, his royal medals, will be handed down with triumph to his collateral posterity, as memorials of his victories. But his WORK; designed by his own genius; executed by his own hand, tracery and all; and every single stone signalised by his own private mark, indelible, characteristic, and inimitable; HIS WORK is the only adequate record of his name. How deeply are its foundations rooted in space, and how lasting its materials for time! It is solid, yet its substantial utility is almost everywhere flowered into beauty. It is mingled in its style, but it is unique. It is the monument, not of the palsy-stricken body, which has returned to the dust as it was, but of the empyreal soul that is with God who gave it, so that the erection knows no place, and can be assimilated to our conceptions only by the figures of fancy and imagination.

The monumental fane, then, which this great investigator has raised in honour of nature, for the benefit of man and to his own glory, is not a camera-obscura, like

the *Work without a Parallel* of old Beccher, or the *Foundations of Chemistry* by STAHL; in which the figures are but dim and upside-down, though lying luminous and beautiful in the midst of the surrounding darkness: nor yet a camera-lucida, like the faultless work of his cotemporary Wollaston; where the images are almost painfully distinct, minute, and suffused with the light of day. It is not a crystal edifice, like the palace of ice upon the Neva, as is the system of LAVOISIER, not yet dissolved by the glowing and ascending year: nor a mosque, like the heretical but prophetic *Chemical Statics* of the metaphysical Berthollet, in which it will ere long be manifest that 'more is meant than meets the eye.' It is not a European museum, like the substantial fabric which the long day's work of Berzelius has slowly builded over his future bed of rest, and filled with all that is rich and rare from Icelandic caldrons, Ural mines, Tropical woods, and the heights of Andes and the Himalaya, for the useful instruction of mankind: nor a half-lit, unfinished, but magnificent orrery, like the *New Philosophy* of DALTON, in which, when the undiscovered planets and the unexpected comets shall have been found, and when the central idea shall have been kindled into a blaze of light and force by the Prometheus of another day, the movements and the sheen of all the stars shall be held up to the astonished eye as one completed microcosm of creation. Yet there is something of all these together in the work of the London discoverer. There are the neighbouring shadows of STAHL, and, as it appears from the researches of Faraday, something also like the inverted representation of truth. There is the brightness of Wollaston, in the great facts he has won from their enchanted holds. There is the sound logic, if not the translucent concep-

tion, of LAVOISIER. There is the breadth, if not the subtlety, of Berthollet. There is the wealth, both of matter and resources, without the infallible accuracy of Berzelius. And, last of all, there is the independence, and the essential vitality of glorious promise for posterity, of our own immortal DALTON: but over the great proportions of the fabric there is shed that brilliancy which is all his own, a lustre partly derived from the accidental character of his particular discoveries, and partly from the original endowment of his mind, by that only Potentate, whose 'minister he was.' Such is the elaborate and richly-laden mausoleum of HUMPHRY DAVY.

THE HISTORY OF SCIENCE.

(LOWE'S MAGAZINE.—Nos. ii. and iii.)

SCIENCE is an ideal of the method of nature, and the production of that ideal is a true creation. By the scientific process there is effected the elaboration of a beautiful orderliness from the midst of a chaos of sensations. This creative work has its succession of era to era, like the geological epochs of the earth, from the genesis of which the conception in hand has been derived. There are the times of palpable darkness, alternating with fitful meteoric gleams which simulate and prophesy the dawn, until the greater and the lesser lights of the firmament at length appear. Nor are there wanting the convulsive throes of an irresistible growth towards perfection; while there are abundant signs that the course of time is by no means in a state of consummation, and that there may be many an epoch beyond the present.

It is as interesting, as it is important, to study this geognosy of science. It is to observe a world of thought evolving at the beseeching, rather than commanding, yet creative word of that humanity, with whose every pulse it is at once our duty and our privilege to sympathise for ever. It is to track the labyrinths of investigation by which the heroes of these new Herculean labours—in hope and fear, in success and disappointment, in sudden flashes of light upon their darkling path, and sudden but long nights of intervening toil, in exultation

and despair, and in the still ignobler struggles with indolence, poverty, and pleasure—eventually achieved their discoveries. It is to notice at what point, and in what attitudes, and with what equipments they successively came upon the field ; and, in fine, to see their great positions methodically delineated on the sphere of universal knowledge. But, above all, it is to investigate the spiritual laws, in the expression and illustration of which the procession of science advances in history, all unconscious though the great discoverers themselves may sometimes have been of the functions they subserved in this dispensation of the providence of God.

Everything that is human is possessed of an ineffable charm for the heart of man. We all belong to one another. In a certain point of view a hive of bees is only one multitudinous individual, and so is the family of Adam. Each of us is but a member, or a fibril, or a particle, infused with the common life of all. The race is one great, long-living crescent and aspiring unit. We cannot a moment escape from the feeling of this pervading and inclusive existence. Even hatred and contempt cannot divorce us from the swarming individuality of human life. It shuts us in like a horizon. The boundary is impassable : but it is a circle, and therefore possessed of an infinite number of sides ; ~~so that~~ no one is limited by the indissoluble association.

Now naked science is cold and repulsive, except to the initiated and the predestined votary ; but, clothed with its own biography, it becomes instinct with the warmth of life for all. Science considered historically, with a view to the illustration of some great principles of human nature, is a section of the universal biography of man ; and it is second in the importance of its lessons only to the history of his religion. In a word, while it seems to

be impossible for the profoundest investigator to acquire any deep insight into science, unless his researches be raised upon the study of its growth from the earliest germs within the general mind, there can be little doubt but that the historical one is the best method of teaching science either to the particular student, or to the man of general but exalted cultivation. The particular student, indeed, can read and methodise for himself; and, if he be worthy of the particular study he pursues, he will never cease to bend with enthusiasm over the letter of his history, until all the affections of his intellect become inalienably assimilated with its infolded and unfolding spirit. It is not till he has done this that he becomes an astronomer, a chemist, a physiologist, a psychologist, an economist, a philologist, or a theologian, deserving of the honourable name. He is a novice or a pretender, and has not yet acquired the right of the sorrowful Correggio, to exclaim with satisfaction, 'I too am a painter.'

But so far as the man of general culture is concerned, it is a pity there is so little help for him in connexion with this subject. It is impossible to know all the sciences; yet it is very desirable, and it might be done in a manner which would secure everything that is best in each and all of those sciences, for the intellectual nutrition of any one who could put it in practice. It is not the particular facts of a science that constitute its vitality, but the generic facts or conceptions to which they have elevated the mind. Facts are the body of science, and the idea of those facts is its spirit. In order that the poet, the artist, the man of letters, the politician, the professional person, or the man of general culture should become possessed of essential science, and crown himself with the very flower and fruitage of the long year of investigation, it is not necessary to enter the observatory, the laboratory, the

museum, or the dissecting-room. Nor must he peruse the best text-books. The superficial volumes of popular science will not serve his purpose. It is another and a new class of works that is wanted. These must be brief and sculpturesque. They must at once lay bare the spirit of science after science. They must exhibit the ideas of the sciences, and illustrate these ideas by as few and as principal facts as possible ; containing shapely principles, and not a huddle of elementary observations. They must be metaphysical, rather than physical treatises. Their authors must have the same kind of ends in view as the wiser teachers of the mathematics. It is not the mathematics but a mathetical way of thinking, not natural history, but a classific way of thinking, and not natural philosophy but an inductive way of thinking, that are to be shed into the mind of the general student. To be still more particular with examples, the astronomer (and he must be a discoverer, that is a man of toil and true insight, who has become painfully penetrated with the ideal of celestial order), the astronomer must write upon astronomy, for the use of the highly-educated portion of the community, in such a style as to train the cultivated intellect to ponder all great things with a constant reference to the difference between the truth of appearance and the truth of reality. The atomician must discourse about the invisible and imponderable objects of his almost spiritual and very complicated but inexorable inquisition, so as to teach the art of reasoning from the seen to the unseen, with a degree of rigour so relentlessly practical as to render the genuine chemist a perfect union of the philosopher and the artisan. And so forth ; for, in a word, every science, every noble art, and even every useful art has a particular habit of mind and disposition of the affections which it induces in him who

pursues it. The mechanical inventor, the scientific investigator, the artist, are consequently partial and fragmentary ; and they are content to be imperfect for the love they bear their art, their science, or their invention. The union of all their habits of emotion and thought, gathered from all the variety of the nobler avocations, in one individual, would constitute him a man of general culture in the largest sense of the phrase. The essences of all pursuits, embodied and harmonised in the person of one man, would constitute the very symbol of humanity.

Goethe realised this conception of a well-developed man more approximately than any one has ever done. He walked with conscious rapture among the great paintings, sculptures, and edifices of the world, imbibing at every pore the ideas with which they overflow, and appropriating the methods of their organisation. He wrestled with the sciences in quick succession, and would not let them go until he had caught and assimilated the fine spirit of one after another. He studied religions, philosophies, mythologies, languages, literatures, dynasties, communities, individuals, and always with an unforgetful reference to the reaction of those multifarious studies upon the structural and functional development of his own nature. Like a lowlier, but perhaps a better man, he 'hunted after all the lawful knowledges of the sons of men ;' and many an unlawful one besides. In the unrelenting pursuit of an elaborate self-culture, this princely man was even too princely in his means. The very vices were cited and compelled to teach him. Nothing was too sacred to be prostituted for the nourishment of this aspiring soul. All sensations, all consciousnesses, all experiences, must be enjoyed, or endured, by him for the purpose of tuition. Lover and friend must

be sacrificed, for the sake of the remorse in the one case, and without remorse in the other. Inexorably did he pursue his assimilative career. But he became a glorious phenomenon rather than a noble man. His accomplishments were vast and manifold, his knowledge was immense, his insight was wonderful, his art was consummate, his very manners were royal; and when he confronted Napoleon, the incomparably more limited, but not more selfish Emperor, is reported to have muttered, 'C'est un homme,'—That is a man!

But such extensive and exalted culture of the intellect is not necessarily accompanied by so much sacrifice of the heart. In these days of extreme subdivision of labour, a manly cultivation of the whole being is very rare. The race is gaining at too great a loss to the individual. We want men as well as painters, astronomers, and logicians. Science constitutes one-third of the essential culture of a manly character; philosophy and art being the remaining co-efficients in the production of such a character; and the united effects of the three are capable of being truly exalted only by the right direction of the Godward affections of the soul. Religion, pure and undefiled, is the communicated but the vital principle of the spirit, and it can be brought out into the noblest development, solely by the conjoint influences of philosophy, art, and science. Now, in so far as the sciences are concerned, a general culture can be effected by their instrumentality, and can be rendered attainable by ordinary diligence, only through means of the presentation to the world, on the part of the thoroughly initiated disciples of the several branches of science, of some such works as have been described above. The spirit of science must be displayed, in all its multiformity, to the general mind, by men who know that spirit; and the

explication of such essential science, in the order in which it transpired in the career of history, would consummate the desiderated education of which we speak.

As a sort of introduction to the study of the sciences, supposed to be carried on with a view to spiritual culture, this essay shall be devoted to the consideration of the germinating process, and the subsequent growth of the theory of Nature; and that in a very easy and general style of both thought and expression.

On the very threshold of the subject, it is evident that there are two very different elemental influences to be taken into account in analysing the history of science. The first of these is the fundamental constitution of the nature of Man; while the second comprises all incidental and external circumstances, such as the midway position of Man between stars and atoms, local government, climate, and all accidental properties and occurrences. The former is germinal and fixed; and its outgoings may be generalised into equally fixed and germinal principles. The latter is circumstantial and variable, so as to defy human method; and it can only be exemplified by selected instances. It must be considered, however, that, if we knew the method of Providence, the history of chances and coincidences would undoubtedly be discovered to be as harmonious as that of the inherent attributes of Nature and Man.

The philosophical manner of contemplating the phenomena of history is that which holds in view the enunciation of certain less or more general principles of development from the interminable multitude of historical records. It is the business of the philosophical historian not only to penetrate to the idea of each epoch, but to generalise his laborious reflections, till he reach the law according to which the succession of time to

time is regulated. His function is the reverse of the poetical historian's, whether epic or dramatic. He must not be concrete and emotional, but abstract and intellectual. His contributions are given to the philosophy of the mind, and the poet's to the natural history of the heart. The synthesis of the characters and functions of these two great species of historical composers would constitute the Utopian possibility of a perfect historian. Carlyle, in his *French Revolution*, has gone nearer the realisation of this ideal union, than any other writer; his figures are glowing men, and his principles are statuesque abstractions. Cousin, on the other hand, has communicated something very like the sacred fire of actual human life to the remotest of his fine abstractions. It is so impossible to apply scientific definitions, with anything like rigour, to the varieties and individuals of a species. But classifications are eminently useful notwithstanding, especially if it be constantly borne in mind that neither Nature nor Man admits of a mechanical analysis.

Since the introduction of the philosophy of history, to use a phrase of Cousin's, several acute investigators have endeavoured to expound the law of the development of scientific knowledge, and none with more success than M. Auguste Comte, so far as his view extends; so far, that is, as it is positive and not negative; and this is an all-important limitation, as shall presently appear. In his celebrated work, *La Philosophie Positive*, Comte announces and explains what he conceives to be not only a momentous but a definitive discovery, viz., the central and inclusive law of the growth of scientific theory. He first generalises this conception from the facts of history, and then tries to show its conformity with the intimate nature of man himself, at once the

author of science, and the object of history. Instead of analysing his views from beginning to end, it will be better to follow the dogmatic way, and simply lay down the general tenor of his doctrine, along with a running commentary and illustrations of our own.

There are, then, three great eras in the history of science,—the religious, rightlier named the superstitious; the metaphysical, better called the abstractive; and the positive. The first and second are transitory; and the third, according to Comte, is consummative and enduring. It will be asserted, in the sequel, that the positive era is no more conclusive than are the abstractive and the superstitious ones; but, in the meanwhile, the formula of Comte may be made the thread of some interesting and useful reflections.

I. In the infancy of his composite life, Man, instinctively eager to know the nature of things around him, in preparation for the profounder knowledge of himself, and compelled, by his primitive ignorance of the too manifold details of Nature, to speculate, proceeds straight to the divination of the first and final causes. He is oppressed by the immediate presence of the crowding and always wonderful phenomena of external creation; and he must find a refuge from their dizzying and stupendous multiplicity in some one supposition of unity or another. With him, however, hypothesis is not the art of investigation, but an instinctive effort to restore the equilibrium of the spirit. It is less intellectual than emotional. It is not a remote abstraction, but an urgent personality. Warmed by the sun, cooled by the breeze, refreshed by the shower, on the one hand; and driven, terrified, and destroyed by the contending forces of nature on the other, he cannot at once find out the causes

of these things, although his impending interests appear to be ineradicably connected with the discovery. The experience of defeated and again defeated inquiry, has not taught him to observe first to be sceptical, and then to generalise. Add to these considerations the fact that his heart is still open to the hint of Divinity that resides and radiates in every particle of dust, in every lotus leaf, in every beast of the field, in every bird of the air, in every star, and in every man. He has not learnt the laborious heresy of a later epoch, that creation is a molecular machine constructed by God, launched into space, and left there to perform its involutions and its evolutions in obedience to certain irreversible laws. For him the Creator has not yet withdrawn from the creation into some fantastical Olympus of His own. Everything is still full of wonder. Everything literally, and not figuratively, flows over with causes of wonder; fear or hope, terror or joy, despair or exultation, he knows not which. Every single form is a symbol of the whole, the whole being a symbol of the infinitude of every quality. He touches immensity at every point. He feels himself the centre of an immeasurable glory, and he directly refers the phenomena of existence to the effluences of Divinity. God he cannot name nor conceive of; but these effluences of the Divine unity are susceptible of fictitious representations to the constructive fancy of even the humblest child. Benignant, or else malignant spirits of the air, the earth, and the water, are, accordingly, the supernatural causes of natural effects in the earlier methodology of the world, and they serve to represent the dawn of the first religious era of human science.

This is the germination of the rudest form of Pantheism, or the worship of all things as substantially Divine. It so rapidly converges, in history, towards a regular

Polytheism, or the worship of many individual things as the peculiar symbols of the substantially Divine, that, so far back as even traditionary records extend, the several peoples of the younger world have signalised different objects, or phenomena of nature, with their adoration. The Guebres worship the revelation by fire; certain tribes in the Russian empire, prolonged in childhood to the present day, are overawed by the mystery of the blasts and breezes, descending dew and rain, snow and hail, clouds and meteors; and they religiously endeavour either to appease or to outdo the Tengri, or powers of the air. That which is unfathomable in the expression of the animal form is more significant to others; and they exalt the lama and the cow, the horned bull and the subtle serpent, to the symbolical dignity. The majority of Pagans, however, construct unshapely images of something like themselves, but expressive of indefinitely greater fulness of the qualities they dread or love. The lawless shapes of their gods of wood, and stone, and metal, seem to be the dim and brutish exponents of their unspeakable sense of the infinitude of Deity. God is above law; and it would appear that human nature, sinking ever so low, cannot lose the apprehension of this transcending truth.

There is no question but this is the idea of heathenish idolatry, and not the reality. It may be thus, however, with a truly spiritual-minded Pagan. The multitudes of the human family continually fall down from sublime symbolism to devilish idolatry; and it has not yet fared much better with Christianity itself, if the vast and populous churches of eastern and western Christendom be included within the pale of Christianity. There are possibly a true Paganism and a false, just as there are actually a genuine and a spurious Christianity;

and it is with the illuminated idolatry, that is, with the idea of heathenism, that the present investigation is concerned ; and it will be abundantly evident in the sequel, that we are very far from being the apologists of idolatry.

In this initiative era of Man's questioning of the meaning of Nature, the arts are not scientific. Processes are reached by rude unconscious methods ; just as many an excellent device is invented, from year to year, in the most cultivated times. Those mighty inventors, who first subdue obdurate matter to their wills, achieve their Vulcanic labours under the impulsion of enthusiastic sagacity, rather than the guidance of intelligent research. Then this fact reacts on the polytheistic theory of the universe. We have been reminded that such men as snatched the spark from flint, or rendered iron malleable and plastic in the hand of ingenuity, or cultivated grains, are in reality the memorable though forgotten endeavourers who, by the perpetually repeated realisation of their vivid conceptions of the forces of nature, assist in the building of our houses, the tilling of our fields, and the providing of our daily bread and raiment, even in the nineteenth century. Nor is it now to be either wondered at or regretted, that the polytheistic heart of the nations elevated the memory of such incomparable benefactors to the highest symbolical places in their grateful homage. A man of great purposes and mighty prowess is actually the highest visible symbol of Divinity for every age, and it is the duty of the Christian to look upon him with boundless gratitude and love ; not, indeed, as an autocratic individual, and far less as a necessitated organisation of some nine or ten chemical elements, but as the gracious and beautiful gift of the most high God. That the early nations

hastened to the deification of the early thinkers of the world, was certainly a sign that they had forgotten the one living and true Jehovah ; but it was natural ; and it was not ignoble, when compared with the practices of modern Europe.

But, to return to the adoption of the present tense, for the purpose of brevity and sympathy, there are greater interests than the useful arts, howsoever victorious. There are wisdom, song, laws, war : and the idea of the sage, the poet, the lawgiver, the warrior, is lifted up by the imagination to the heaven of gods. The Divine councillors themselves must have a god of gods ; the father of the gods ; Diespiter. In this manner does the polytheism, which so soon curdled out of the indefinite pantheism under which the human mind fell prostrate when the tumultuous creation burst in the beginning upon its view, tend to crystallise into a definite monotheism, or worship of the monarchy of heaven and earth. It is also worthy of the most serious consideration, that, although all this is superstitious, it is pious in some degree, for it embodies a very humble, though a base, faith in the godhood that created and continually re-creates the universe.

Such is this dawn of theory. It stretches its influence far down in history, after what is ordinarily called idolatry has passed away ; and, in truth, it is this which belongs to the subject under discussion. The earlier astrology and alchemy (for there are two well-marked ages of them both) were the embryotic sciences of astronomy and chemistry, in the course of passing through the first stage of development to the second. The popular idea of the former was the supposition that the stars beam and move with the light and will of inhabiting spiritual essences, and that they magically

influence the destinies of mankind. According to the latter, there are four elemental principles of all material forms, with a quintessence as the ideal principle of these four elements themselves; but the substantial ingredients of the world would have been only the dead remains of nature without the supernatural creatures that agitate and warm them with the activity of life. The salamander, the sylph, the gnome, and the nymph needed to be invoked before they could be swayed by the magus.

Even in the middle days of alchemy, after the earlier crudities had been discarded, and men like Roger Bacon, Arnold of Villeneuve, Raymond Lully and others, had betaken themselves to laborious experimentation, the chemical union of two substances continued to be represented under the similitude of a transcendental wedding of the living forces of the bodies. Some one has jocularly observed, that the contending schools appear to have explained the processes going on within their crucibles and alembics in accordance with the views they respectively entertained of the relative qualities, the most favourable to the happiness and endurance of the matrimonial alliance. One teacher upheld that difference of nature and habits, and another that similarity of these, is the more propitious to genuine combination; and it is curious to observe that this is the very question, in a shape adapted to the advancement of the science, which has already begun to agitate the Lavoisierian theory of chemistry. In those days, however, the metals were suns and moons, kings and queens, red bridegrooms and lily brides. Gold was Apollo, 'sun of the lofty dome;' silver was Diana, the fair moon of his unresting career, and chased him meekly through the celestial grove; quicksilver was the wingfooted Mer-

cury, herald of the gods, 'new-lighted on a heaven-kissing hill ;' iron was the ruddy-eyed Mars, in panoply complete ; lead was heavy-lidded Saturn, 'quiet as a stone,' within the tangled forest of material forms ; tin was the Diabolus Metallorum, the very devil among the metals : and so forth, in not unmeaning mystery.

There were flying birds, green dragons, and red lions. There were virginal fountains, royal baths, and waters of life. There were salts of wisdom ; and essential spirits so fine and volatile, that drop after drop let fall from the lip of the wonderful phial that contained them, could never reach the ground. There was the powder of attraction which drew all men and women after its possessor ; and the alcahest, or universal solvent and Noli-me-tangere of essences. There was the grand elixir, which conferred undying youth on the glorious mortal who was pure and brave enough to kiss and quaff the golden wavelet, as it mantled over the cup of life : the fortunate Endymion of a new mythology. There was the philosophical stone, and there was the philosopher's stone : the former being the art and practice, the latter the theory and idea of turning baser natures into nobler : the theory and the practice of exaltation. The philosophical stone was younger than the elements, yet at her virgin touch the grossest calx among them all would blush before her into perfect gold. The philosopher's stone was the first-born of all things, and older than the king of metals. In the famous dialogue of the Ancient War of the Knights, he exclaims, with fond remonstrance, 'My dear gold, I am older than you !' In a word, there was an unbeginning and an interminable imbroglio of a few of the hard-won facts of nature, a multitude of traditionary processes and results, several very just analogies, some most fantastical notions, one or two profound but in-

tractable ideas, a haze of philosophical mysticism, and an under-current of fervid religiosity. And this seems to be the place to assert, in vindication of the adepts, that while chemistry is the easiest of sciences to study, it is the most difficult to discover. It has come through a most wonderful labyrinth already : and there is a world of perplexity in the abysmal background of the scene.

It might perhaps be argued, in this place, that the terminology which has just been exemplified was employed by the masters of the arcana for the purposes of an exoteric costume, in order to conceal the inner forms of their discoveries and doctrines from the vulgar eye. It was understood to be allegorical by the initiated ; but still it was the emblematical expression of the great misconception of this age of alchemy, which implicitly asserted the gratuitous proposition that the interior agencies which keep the world in motion and life are personal forces, essentially out of and above nature. It was a sort of scientific polytheism. These organic wills, underlying and sustaining the parts of nature, were thrust between the one God over all and His creation. Nor is this an unmitigated error. There is recognised in it, to say the least, the necessity of an unreposing and continuous act of will to the sustainment of the universe. It seems to have implied that the Divine Being is literally the upholder of all things. They delegated the volun-tative energy, however, to fictitious ministers. Yet they did not lose hold of the greater truth in constructing the minor error. Indeed, there surely never was nor ever will be any system of error, from the poorest superstition to the most self-forgetful atheism, without its seed of truth for its votaries, its lesson for us, and its incalculable value in the economy of history. It is possible, for example, that even in the crudest of the forms assumed

by mediæval alchemy there may lie concealed one of the elements of a higher chemistry than has yet appeared. Moreover, this is only a passing glance at the science of the middle ages, in its transit from the first to the second period of investigation ; the latter of which is now to be the object of as cursory a survey.

II. This is what Comte calls the metaphysical era. He does so, it would appear, in that sort of vain despite against metaphysical studies which men of physical pursuits are prone to imbibe. It is done in ignorance. They despise that for metaphysics which is not metaphysics at all ; or else they fail to grasp the purport of true metaphysical investigation. Sure we are, at all events, they do not learn their ignorant contempt from nature or the natural sciences. The analogy of natural science should, indeed, rather suggest the possibility of a noble metaphysics. True natural philosophy (that is, such sciences as astronomy and optics, not the like of chemistry and medicine) consists in the application of mathematical law to the theory of sensations, and the discovery thereby of the spherul harmony subsisting between the universal idea and the particular phenomena of the sensible element of the universe, namely Nature. True metaphysics (that is, not the psychology of the British school from Locke to Thomas Brown, nor the phrenology of Gall and Combe) shall consist in the application of logic, or the philosophy of the laws of thought in the abstract, to the theory of consciousnesses, and the discovery thereby of the everlasting harmony subsisting between the universal idea and the especial phenomena of the conscious element of the universe, namely the Spirit. Plato denominated these harmonies the music of the spheres.

In the confident expectation, then, of a genuine meta-

physics returning to the world, it is more becoming to speak of this second epoch of scientific history as the abstractive or the impersonative one. The reasons will be obvious in the sequel of the paragraph. Man is, by this time, disabused in some degree of the impotent practice of diving at once into the infinite for first and final causes ; but he is yet unable to pass from the child-like superstition of the religious to the fearless scepticism of the positive era. He enters a time of transition from one to the other. He now traces the appearances of Nature, not indeed to supernatural agencies, but to imaginary causes. Some of his theories of natural causation are merely the personified abstractions of the mind ; and others are only insignificant verbiage, by which he manages to hide his ignorance, and mistake a synonymous definition for a veritable explanation. The natural science of the Greek sages was in such a stage as this. Their national mythology, indeed, had long been culminating towards a similar consummation. The denizens of Olympus, shadowed before the general mind in Orphic hymns, Pindaric dithyrambics, the works of Phidias and mighty sculptors, priestly rites and public games, had become the symbols for the reflective of whatsoever was godlike in man, and in the universe of which he is the centre. Contemplated from this point of view, that grand mythology was the magnificent expression of much that shall for ever be beautiful and true. The whole theogony was a scheme of more and less specific conceptions, derived from the observation of everything that appeared to be potent, good, and graceful in the life of man, and then solidified by the magical rod of a creative imagination, into a statuesque gallery of noble impersonations. For the vast mass of the people this was always superstition ; but alas, it is the same with the Christianity of

Europe at this boastful hour. It must be confessed, and not without the profoundest sorrow, that it was nothing but an enormous national idolatry; with which the theocracy of the Hebrews now stands in glorious contrast, in the dim-lit vista of the past. Yet we own a pitying love for all the aberrations of humanity, and cannot withhold a charitable plea for 'the large utterance of those early gods,' to whom we were taught to render the graceful homage of a poetical faith in the Greek-like days of youth. It was a gross, but a fanciful, system of idol-worship among the people. So far as the lighter poets and the slenderer thinkers were concerned, it was probably a fantastical fiction, which was neither heartily believed nor cordially rejected. But for Socrates and Plato, and the wonderful scholars whom these immortal memories represent, it was a sublime symbolic mystery. The former of these sages, condemned to die for infidelity to the gods, offered a memorable sacrifice to Æsculapius, in order to signify his holding by the Olympian mythology, as the popular exponent of his own theology. At all events, in the philosophy of Plato, there is apparent the re-aspiration of the religion of the Greeks from the superstition into which it had universally sunk towards a mystical faith, which would have been incomparably better if it had been susceptible of popular realisation.

The principal error of the Greek schools of science proceeded from a similar exaggeration of the province of philosophical abstraction. They mistook the immaterial creations of the intellect for the essences of outstanding realities. Their confidence was in the course of being transferred from the world without to the greater world within; and, trusting too presumptuously in the apparent omnipotence of human reason, they became minded to decree the laws of the former like the gods. To illustrate

this more particularly, we may popularise an instance or two.

The most famous of the ancient theories of the perception of sensations was something like this: In every change a body undergoes, there must exist, in the original form, and in that into which it is changed, something which is the same in both, and also something which is different in each. When a flower withers and decays, the stuff or subject-matter is still the same, and, therefore, that which made it once a pleasing object cannot have been the subject-matter. There must have been two principles in the lovely original; the material substance of which it was constructed, and something else which communicated the shape and qualities of a flower to that indifferent substance. This animating principle is the specific essence or soul of the flower. Every individual figure is possessed by its own specific essence, while the material ingredient is the same in all, being more or less in quantity in this creature and in that. Then philosophy has to do with universals. The philosophical mind, thinking of the rose, does not conceive of the bodily presence of any particular plant, but of that which is common to all the genus. One may be taller, greener, or leafier, than another; but that depends on the material part. It is not the matter or body, but the specific essence or soul of the rose that conveys the conception of a rose into the mind. Hence arises the notable conclusion that the said specific essence is itself the image of the flower, propagated in unceasing undulations, very much as the odour of musk or camphor is supposed, in the nineteenth century, to be shed around these substances.

Nay, this is refined upon still farther. Our rose-tree is the compound of matter and an image; but, as most

substantial forms are capable of making themselves known to man by the medium of all his five senses, they must all contain and radiate so many specific essences, and thence the terms, audible species, visible species, and so on. Such was the Aristotelian doctrine of perception, in which the classic abstractions of the modern botanist, to keep by the instance of a flower, are substituted for actual externalities.

In the Greek physics it is much the same. Take, for instance, the far-famed demonstration of the infinite divisibility of matter, which almost rings in our ears yet : Whatever is possessed of length and breadth is necessarily divisible ; therefore, if a piece of matter be supposed to be broken down till particles ever so small be reached, still these particles must have length and breadth, and must be divisible ; and so forth, through an endless series of subdivisions, so that matter must be infinitely divisible. Now, this is arguing from sheer space to palpable matter. It is an embodiment of the abstract conceptions of length and breadth, and that embodiment is mistaken for actual substance. It demonstrates that an atom is mathematically divisible, but not that it is physically divisible. It has nothing whatever to do with the atomic theory of nature. Yet it was the Stoical argument against the tenet of Democritus.

All the natural sciences were infected with a wretched imitation of this erroneous method of philosophising upon nature, until the influence of Bacon and the example of Newton put it for ever to shame. Nature abhorred a vacuum till the sixteenth century. Medicine had an Archæus and subordinate vital spirits. Chemistry retained phlogiston till near the close of the eighteenth century. Qualities were put for things. Abstract conceptions of forces and of forms were every-

where personified, and then supposed to be the causes of the former, and the constituents of the latter. And there is the same remarkable tendency to the convergence of principles in this as in the previous era. The number of imaginary forms is gradually diminished as it advances. When physiology, for example, approaches the close of its second stage, all the deceptive nouns-abstract, with which the vocabulary of its history is overloaded, become summed up in one: the *vis medicatrix nature* or the vital principle. The respective solidified principles of the entire range of the sciences culminate at last in the word Nature, understood as the great productive source of things.

It is not to be supposed, however, that this kind of investigation never met with opposition till the revival of letters in modern Europe. There were the empirics, or men for experience among the Greeks, and the immortal Democritus was one of them; and the school of Epicurus, who professed materialism, a utilitarian system of virtue, and the atomic theory of Democritus. There were the Sadducees among the Jews, who denied the spiritual element of man and the resurrection. But both these great sects swung so ponderously to the opposite extreme, as to land in a universal scepticism; and they ended in professing errors more momentous than those against which they obtruded their protest. In this way the better influence of these movements was greatly neutralised.

In the long career of mediæval history, also, many a stout inquirer stood forward on behalf of observation and the facts of nature, before Descartes' and Bacon's immortal works on methodology. These arose principally among the alchemists and their immediate followers, who were the true inventors of the art of experimenta-

tion. Indeed, Roger Bacon, Albertus Magnus, Arnoldus de Villâ Novâ, Raymond Lully, Basil Valentine, and even Bombastes Paracelsus, made an immense number of experimental trials of the properties of matter, and described the results with precision. The greater alchemists never meddled with the stone, but were content to assert their belief in it, or perhaps to transmit a process for its preparation. Friar Bacon distinctly states that he did not know and did not seek the golden secret; but he seems to have had no doubt of its existence. He asserted that experience is equal to reason in physical science. The whole class of indomitable workmen, of whom he is still the best as he was the earliest specimen, left the pursuit of the grand arcanum altogether out of view. It was processes for gunpowder, for essential oils, for spirits, for acids, and for wonderful salts that they sought. They rested a speculative and a historical faith in the philosopher's stone; but that was so distinct from the experimental element in their character, as to fall separate from it in the persons of their immediate descendants in research. Soon after Paracelsus, the adepts of Europe spontaneously divided into two classes. One of these comprised very weak men, who rode the speculative hobby of the older school. The other contained men of diligence and sense, who devoted themselves with infinite labour to the discovery of new compounds and reactions. Although they were rather pedantic artisans than men of science, it was more particularly in their persons that the so-called metaphysical era of scientific history was aspiring toward a higher stage of development. The abortive efforts of the Greek empirics and the Jewish Sadducees, and the exemplary influence of these worthy practical chemists, were at length crowned by the advent of the epoch of positive inquiry, which is

now to be illustrated. It is worthy of particular observation, however, that this impersonative sort of methodology has by no means entirely paled before the light of modern science, considerably prevalent though the inductive method has happily become. There are still vital principles in physiology, calorics in chemistry, electric fluids in general physics, luminous ethers in optics ; and it is only in astronomy that there lingers nothing of the kind. There is no historical boundary, indeed, between era and era. The epochs blend with one another. There are both superstition and metaphysics in the natural science of the present time.

III. Although the third or positive era of science has been long approaching, or rather although it has always existed in the world, the time of its decided preponderance is always to be dated from Descartes, Bacon, and Newton. The first of these illustrious discoverers may be considered as the prophet, the second as the legislator, and the last as the purest example of the new method. These great men, leading the victorious army of positive investigators, have once for all exhibited the vanity of the proud attempt to proclaim laws to Nature from the throne of human reason, without first studying the innumerable and infinitely varied characters of what they would subject to her dominion. They have inculcated and exemplified the art of observation.

The workmen of this period vie with one another in the discovery of simple facts, and then they proceed to extricate the natural relations of such facts as they can discover, without haste and without ceasing. They know, and that feelingly, that everything higher is beyond their reach. Accordingly, they hunt down the manifold details of Nature with unwearied diligence and inexorable

accuracy. No toil is too great for them ; no protracted hope too painful to endure, with the secret trial of humble devotion ; and no stranger can intermeddle with their joy. While not a single observation is overlooked as unworthy of notice, they pursue the more intimate processes of Nature with greater ardour than the more external of her phenomena ; and that with the well-grounded expectation of laying hold on central discoveries, which shall be clues to whole spheres of inquiry. Meanwhile they are continually translating particular instances into the language of general facts or theories ; collating, comparing, and running down analogies, which become the starting-points of still another and another chase, until the successive huntsmen rest from their labours in the grave. They appropriate the aspiration of the poet of the Seasons, and are content to realise it in any manly degree before they die :—

'To me be Nature's volume broad display'd ;
And to peruse its all-instructing page,
Or, haply catching inspiration thence,
Some easy passage, raptured, to translate,
My sole delight !'

Every now and then there arise stronger intellects than even the swiftest of these ; and they translate the very general facts which the former have written down into the language of facts more general still, and thus they theorise theories themselves : the word 'theory' standing, in their vocabulary, not for a conjecture, but for the certain statement in one general proposition of all that is ascertained to be possessed in common by any given number of simple facts. And in the greater results of all these busy commingling hosts, there is the same unceasing tendency to convergence towards some unity or

other, as was observable in the development of the two preceding eras. All the less general facts of each science are reduced under one more general than them all, which is the theory, or largest proposition, of the science in question : while the largest propositions, or theories, of all the sciences are visibly concentrating, in the century in which we live, to some one comprehensive theory of force. Beginning almost with a kind of panphysicism, the era towers away up, through a genuine polyphysicism, towards an awful monophysicism ; the last of these being the false god of materialistic, or indeed of all scientific theists. Such is that positive philosophy of modern times, the methodology of which is now so nearly perfect. Copernicus, Galileo, Kepler, and Newton discover the conditions of gravitation ; and they are content to state the law as an ultimate fact. And whosoever is ambitious of explaining gravitation itself, without some radically deeper observations of its scope than these immortal sages have conceived it possible to make, must abandon the positive method of investigation, and miserably fall back upon the middle age of baffled legislation : unless, indeed, he can create a new method, and announce the dawn of a fourth and still loftier epoch upon the world of science.

The first aim of positive science is the collection of facts. It is not the only object of modern science, but it is the great preliminary one. Without facts nothing can now be done ; they are the foundation of the whole superstructure, and they are also the stones of the edifice. Science has now to be rooted and grounded in fact, that is, in Nature. The prime object of the investigator is to discover new facts, whatever may be his secondary and perhaps greater intention with the specific discoveries he may make. It matters little, so far as science is con-

cerned, how these facts are found, so they be found. They may come into the possession of the observer by accident ; or while he quietly stands before Nature and watches her undisturbed procedure ; or while he may be diligently making all sorts of experiments, which are plans of his own for breaking in upon her repose, without any other motive than the expectation of witnessing something novel as the effects of the disturbance he produces. But among the researches of even this humble-minded methodology, it is always regarded as the sign of a vulgar intellect and of poverty of spirit, when one becomes entirely passive among the works of creation, and only watches without design, without expectation, and without hope. Those experimenters, who put no particular questions to Nature, but only agitate her in order to hear what her responses shall be to their puerile curiosity, are despised. Even such eager spirits as are never at rest themselves, and will not allow the object of their greedy investigations to rest either, but persist in making every kind of experiment in the avaricious hope that they shall stumble on something that no other mortal has happened to descry, are tacitly excluded from the privileges of the new fraternity. Bacon compares them to idle, though sometimes fortunate boys who turn up every stone in the channel of a summer stream, in order to take their chance of finding a trout under one or other of them : but they can rarely seize the prey they start, for it glides through their fingers.

The genuine adept in positive science always follows a clue. He generally anticipates the answer he shall receive to his inquiries. At all events, he knows what he is asking, and can at once interpret the reply, though it be negative or evasive. Every observation he makes, every experiment he performs, has a design in it. Every

experiment is a specific inquiry. His formula is, Is it thus or not? Every inquiry is the expression of a conscious conjecture. No great discovery, says Newton, was ever made without a bold guess. Investigation has now become the rigorous and impartial putting of the idea of the investigator to the incorruptible test of fact. That idea is called the mental initiative of the investigation. The greater and more elaborately consistent the mental initiative, the greater the difficulty of the inquiry, the greater the glory of success, and the less the ignominy of failure. The chief source of such mental initiatives, in purely positive science, is the analogy of things. Accordingly, the discoverer is a man whose eye is clear and keen for the thousand-fold resemblances in creation. He is possessed by a sense of the wonderful unity of Nature. Where another sees nothing but difference, he can descry nothing but similarity. It is analogy that fascinates him, and binds him over to the work of unceasing research. Difference is a heart-sore to him : and, in his passionate instinct for simplicity, he gazes into Nature, his eye lighting on every resemblance of things that are yet different, his hand plucking out the secret of that tantalising analogy, and his tongue vindicating the fore-felt unity of Nature.

It is commonly said that Newton, sitting in a meditative mood within a garden one still and sultry evening, was suddenly inspired, by the falling of an apple, with the true conception of the principle of the solar system. This is no more than a sort of classical fable, of course ; but it sufficiently expresses the fact, that the whole fabric of the Copernican astronomy is methodologically founded on the perception, on the part of modern astronomers, of the analogy between terrestrial and celestial phenomena. The method of astronomy is simply this :—A body let

go at any attainable distance from the surface of the earth, instantly falls towards it ; or, in other words, the earth and the body attract one another ; and analogy suggests that it is the same attractive force that binds together the celestial spheres. It is found by experiments, made with ingenious apparatus invented for the purpose, that the law of such gravitation on the surface of the earth is directly as the mass, and inversely as the square of the distance, of the falling body ; and analogy suggests the expectation that the same law prevails within the larger boundaries of the solar system. This simple analogy is the salient point of the labours of Copernicus, Tycho Brahe, Kepler, and Newton. Upon that analogy is constructed a coherent hypothesis, fit to explain the celestial motions. Practical deductions are derived, by rigorous mathematical methods, from that hypothesis ; these practical deductions are watched for in the heavens ; they are universally found to correspond prophetically with the actual occurrences in the sky : and the hypothesis, from which they spring like so many corollæ from a stem, is concluded to be no mere conjecture, but the very truth of Nature. Eclipses, transits, occultations, conjunctions, and other phenomena are not only explained, but foretold, to the very minute and second ; and it is universally inferred that the theory of astronomy must in reality belong to the nature of LAW ; ‘ with which alone dwell prophecy and power.’

We shall never forget the effect of the first solar eclipse we ever witnessed on our heart and mind. It was in the time of dreamy boyhood. A certain sacred majesty invested the anticipated scene in our imagination. A species of terror hung about the indefinable glory we expected. There was as much of fear as of hope, of pain as of joy, of oppression as of exultation, in the mingled

emotions with which we looked through days and nights towards the solemn minute when the darkening of the sun should be begun before us. The day at length arrived—it was a Sunday. The churches were closed on purpose. The streets swarmed awhile, as if it were some judgment-day, and they were then left empty of everything but fiery heat and dust. The Calton Hill was covered as with a flight of bees. So were Salisbury Crags and Arthur's Seat. The Castle, the tops of monuments, the roofs of great buildings, the spires of churches, were all heavy with holiday star-gazers. The hum of the clustering crowds thickened the air. The cry of 'One minute more' ran through the multitude, and all were hushed; but as soon as the shadow commenced to stalk across the glorious orb, the hum began again, smoked glasses were handled, small science was talked, and the people went their ways, glad that they had seen and understood the mysterious apparition. Ignorant savages would have thought it was the finger of God; but the inhabitants of Edinburgh knew it was no such thing! But during the dispersion of the people our secluded heart suddenly expanded, with the triumph of a new joy, from the state of painful compression, which a few preceding days, and especially the hour itself, had slowly but forcibly induced, until it almost reached the degree of total collapse. Who, thought we, who foretold all this? Who bade the churches be shut this afternoon, because the symbol of our Divine Redeemer should be hiding his face? Who has filled the universal heart of Great Britain with the expectation of this hour? Who prophesied this minute? Who has entered so deeply into the counsels of the Almighty, as to foretell the moment of His deeds? Then the thought of Newton, the heroic type of discoverers in the heart of every British youth, came upon

us with fascination more intense than ever ; and we inwardly chanted Thomson's enkindling poetry upon the theme of Newton's achievements ; and we reverberated Chalmers's clangorous eloquence, in the solitude of our own spirit, on the subject of Newton's lustrous character ; and we wept for joy to think that we were born within the immortal land of Newton's birth, majestic accomplishments, and beautiful nature :—

' This happy breed of men, this little world,
This blessed plot, this earth, this realm, this England,
This nurse, this teeming womb of royal kings ;
This land of such dear souls, this dear, dear land,
Dear for her reputation through the world.'

We were afterwards in the neighbourhood when another and a different scene was transacted in a city. It seems to force into striking and interesting contrast the superstitious piety of the religious era of thought, and the rationalism of that positive one, amid the influences of which we live in Great Britain at present. The place was St. Petersburg ; the time, the dead of winter and of night ; the persons of the drama, the Emperor of all the Russias, his nobles and soldiery, and the mob of that gigantic capital ; and the event, a conflagration. The palace was on fire. The flames threatened the Hermitage, with its precious works of art. Red-hot balls of iron had swung up the yard-arms of the watch-towers of the quartals. Cannons had roared out the disastrous tidings, and awakened a terrified reveille. Fire-engines grated along the streets, and across the plains. Water splashed and hissed against the glowing windows, roofs, and walls of the imperial home. The night was thick, dark and gusty. But amidst all the wild contention of the elements, organisation reigned and fought. Everything was done by the military : soldiers dragged the

engines, soldiers filled the buckets, soldiers held the pipes, soldiers scrambled among the ruins, soldiers conveyed away the salvage from the impending wreck, and soldiers kept the people away with bayonets in silence. The magnificent Nicholas gleamed about in the centre of all, the soul of thousands; and his immediate officers were the nerves of every movement that was executed. Meanwhile, the vast crowd of brawny, bearded, and sheep-skinned Russians hung about the regimented multitude of military workmen, like a canopy of cloud about the stately world within. They had nothing to do with their minds; nothing with their hands. They had nothing to do but fear, and hope, and wonder, and await. Meanwhile, a long dense cloud hastened over the burning pile. The lurid light flashed upon its belly. It reflected the torrent suddenly, though dimly, and hurried on its way. A terror-stricken voice exclaimed, Cometa! The cry ran everywhere like wildfire, Cometa! cometa! The affrighted chaos took it for a portent! And thus, not long after the people of Edinburgh had seen nothing more than the intervention of an orb of heavy matter in an eclipse of the sun, the populace of Petersburg converted a cloud into a terrible omen, by the shaping sentiment of superstitious terror.

It is necessary, however, to say a few words in explanation of what has been hinted regarding some deficiency supposed to exist in the merely rational manner of contemplating natural phenomena. This can be the more suitably done, because it will afford an opportunity of illustrating the value of analogy as the source of sublime conjectures, which have often the similitude of truth, even when they cannot be submitted to the test of observation. We need scarcely premise that such conjectures constitute no legitimate part of positive science, although,

when retained in their proper places, they may be both intensely interesting, and even highly important. Such exercises are the noble sport, not the actual work of genuine science.

It is true that suns and planets are more or less composite aggregates of sensible masses of matter. Our globe is composed of earth, sea, and air; the earth is composed of rocks, plants, and animals. It is also true that masses of matter are more or less composite aggregates of atoms. A piece of marble is a congeries of so many particles of carbonate of lime; a particle of carbonate of lime being a congeries of particles of the silver-like metal called calcium, of carbon, and of oxygen; a particle of oxygen, or of carbon, or of calcium, being a congeries of no one knows what kinds of particles. But, however indivisible an atom of any of the chemical elements may be by any forces we are yet able to bring to bear upon it, it is yet demonstrable that a truly simple atom of matter is possessed of no solid central nucleus of substance. Such an atom is a point in space, repelling other such points up to a given distance from itself, then attracting them up to another mathematically related distance, then repelling, then attracting them; and so on in alternating spheres of distance from itself. Bosovich demonstrated that the conception of this is sufficient to explain all material appearances. Faraday, an experimentalist, now teaches something like this. Let the reader suppose it irrefragably established that all the motion, life, and beauty of Nature are produced by the dual forces of attraction and repulsion. Attraction is inverted repulsion, as Newton was careful to observe. Now what is this sheer force operating in innumerable points, in order to the production of a universe of stars? Why, according to the method of positive science,

analogy is the only possible clue. What, then, is known to originate force and produce motion? If any higher thing than force is known to produce force, the argument of analogy shall render it probable that such higher power is the effective cause of these atomic forces also. The answer is immediate. It is WILL. Will alone is known to originate force and motion. There is no limit ascertainable to the might of human will in this direction. It is actually limited only by the strength of human muscle. The voluntative energy will tear the flesh on which it operates. It has been remarked by Isaac Taylor that, if a man had muscles of wire incapable of being riven, and bones of adamant, he might project himself from planet to planet. The application of the argument is evident. It is cogent, though not demonstrative, to the effect that atomic points—not incalculably little dots, but points without length, breadth, thickness, or circumference—are the immediate emanations of the Divine will. In other words, God literally creates the universe every moment. Every instant is a new morning of creation. He is the Alpha and the Omega; the beginning and the ending; the Creator, the Sustainer, the Provider; ‘in whom we live, move, and have our being.’ This is not a discovery; it is only an analogical conjecture of positive science. It harmonises with the pious presentiment of the first era, with the poetic fancy of the second one, and with the enunciations of Christianity. It is pious, it is beautiful, and it is founded on the analogy of Nature. We dare not expatiate upon it; but its relation to the subject under discussion is not far to seek. Let us conclude the paragraph with a paralogy upon three terrible lines from Milton, which, as they stand on his wondrous page, are nothing more or less than the polar reverse of this idea:

'For within us God we bring,
And round about us, nor from God,
No more than from ourselves, can flee.'

In order that we may not come too abruptly down from these heights, or rather ascend again from these depths of abstraction, 'to seek for food, and enjoy the endless beauties of Nature,' we shall give one more illustration of the principle of analogy as the guide to new discoveries. It shall be an instance in which the resemblances are so irresistible as to have won the consent of men of science, while the difficulty of demonstration has yet proved so great as to have withstood every endeavour to make it good by precise research. The Derbyshire spar, of which it is customary to make ornamental vases, is the subject of this analogy. It is more frequently denominated Fluor Spar; the lights seeming to flow and reflow, or, in one word, to fluitate about its substance. It is veined and waved with blue and purple, and many shades of hue. Partly it is of all colours in its interior, and partly it displays the beautiful phenomenon of iridescence on its surface,

'A trembling variance of revolving hues,
As the sight varies in the gazer's hand.'

Yet the chemist has never succeeded in properly analysing this plentiful mineral. But Ampère has shed a very clear light upon its constitution by placing it in the focus of the mirror of natural analogy. In all its chemical properties and actions, this evasive substance presents a perfect resemblance to the chloride of calcium, the iodide of calcium, the bromide of calcium; the chlorides, iodides, and bromides of the metals magnesium, barium, and strontium; and less immediate, but still close affinities to a great number of well-

known compounds. Now all those bodies which this spar resembles are known to be compounds, each of a metal and some more penetrating element, such as chlorine, oxygen, sulphur, or phosphorus. Those which it more specifically approaches in its characteristics are the compounds of earthy metals, such as the metals of lime and magnesia, with one or other of the very characteristic salt-radicals, chlorine, bromine, and iodine, three elements belonging to a well-marked group. But the metal of lime is known to exist in fluor spar; and as it is not the chloride, bromide, or iodide of calcium, the stress of all this scheme of analogies is to suggest that fluor is a compound of calcium and an unknown element belonging to the chlorine group. The unknown element is named Fluorine before its birth into the actual world of science. This supposed constitution explains every fact that is known concerning the spar. The atomic weight of fluorine can be inferred from certain data, and fluorine ranks in every table of the elements as a salt-radical, the atom of which is eighteen times heavier than an atom of hydrogen. The reason that fluorine has not yet been separated, and presented to the eye and instruments of the chemist, is the potency of its reactions. No vessel within which it can be freed from the calcium with which it is united, is capable of resisting its attacks. It seems to be a kind of alcahest or universal solvent. Mr. Knox has ingeniously endeavoured to elude this difficulty by the employment of an apparatus made of fluor itself, and has procured an orange-coloured gas, regarding the integrity of which there is still room for doubt. Faraday has partially confirmed this observation. Still fluorine has not been indubitably isolated, and the belief in its existence continues to rest upon the perception, in the

general mind of chemists, of the analogies of Nature. In a word, the presentiment that Nature is multifariously One, is at once the deepest conviction and the dearest emotion of the man of positive science. Newton, observing that the diamond is a powerful refractor of light, and that the other strong refractors with which he was acquainted were combustible bodies, ventured to predict that it would one day be found to be combustible also. Accordingly

‘The lively diamond,
Collected light, compact,’

was not long of taking fire in the concentrated heat of the burning mirrors of the Florentine academicians, and being dissipated in the air. Hoffmann discovered, that when charcoal enters into combustion, it simply dissolves in the atmosphere, producing choke-damp. Black found that choke-damp is fixed in the substance of marble, and is an acid neutralising the causticity of the lime. It is unfixed and set free by the operation of kiln-burning, and quicklime remains behind. Priestley observed that it is the same fixed air, choke-damp or carbonic acid, that is developed during the process of fermentation, and communicates briskness to malt liquors and effervescing wines. Lastly, the researches of Allen and Pepys, Tennant and Davy, established the proposition that the diamond is the pure and crystalline principle of charcoal, being wholly converted into carbonic acid gas by the act of burning. Carbonic acid is composed of carbon and oxygen; water of hydrogen and oxygen; and hydrogen and carbon both produce heat and light when combining with the oxygen of the atmosphere. And thus, to quote the language of the greatest English writer on methodology since the time of Bacon, Coleridge, ‘water and flame, the diamond, the charcoal, and the mantling

champagne, with its ebullient sparkles, are convoked and fraternised by the theory of the chemist. This is, in truth, the first charm of chemistry, and the secret of the almost universal interest excited by its discoveries.'

Enough has now been said for the purpose of illustrating the proposition that analogy is the very thread of the labyrinth in the investigations of science. It conducts to every new fact of importance, and it never fails to conduct to important ones. The essential quality of a discoverer is an inevitable eye for the secret resemblances of things. He must also be a man of quick invention, swift and sure to devise ingenious plans for the practical realisation of his conjectures. He must be patient and humble, always willing to modify his first conception by the results of observation, and rejoicing even to sacrifice it altogether on the altar of Nature. But, above all, he must be persevering, clinging by his thought, yet prepared to relinquish it. He must remember that, though 'hope deferred maketh the heart sick,' every year and lustrum of perplexing and weary research are but

'The still protractive trials of Great Jove,
To find persistive constancy in men.'

Newton said he owed his discovery to 'always thinking at it.' All would say the same, from Copernicus down to Dalton. Let a man erect a coherent hypothesis on the rooted analogies of Nature, and he is bound to cherish it by a sort of lifelong sacrament. He will rise or fall with it; and he must not care too much whether he shall fall or rise. He will yield to the soft compulsion of his idea, and suffer himself to become possessed by it. It will accompany him at home and abroad, and go with him to foreign lands. It will rise with him, and

lie down with him, and chase him through his sleep till he awake to another day of work. Even when he joins in the 'carouse of wine,' or mingles in the society of the gay, or reads philosophy, or contemplates works of art, or 'yields him up to love's delicious harm,' it will be continually whispering within his soul

'Set thyself about it, as the sea
About earth; keep lashing at it
Night and day!'

The collection of facts is not the sole object of positive science. Properly speaking, it is a very inferior object of it. Facts are necessary; they are of immense practical utility, and they are beautiful in themselves. To the wise, says Emerson, a fact is a beautiful fable; but it must be added, that it is only as the symbol of an idea. The higher purpose of science is the systematising of facts. The philosophical man of science pursues the discovery of the relations of facts. There are three kinds of relationship among facts: the relation of like-unlikeness; the relation of invariable concomitance; and the relation of necessary consequence. All the facts of Nature, classified according to these relationships, would be the perfection of positive science, and that great system would be Man's ideal of Nature. We do not here take up the popular explanation of this methodology of the positive sciences. It is sufficient for our present purpose, if the reader clearly understands that the only objects of positive science are the discovery of facts and the elaboration of the natural relations of facts.

Such are M. Comte's three eras of the growth of human knowledge. They are the childhood, the youth, and the manhood of science. That which he seems to discover in the history of the general, he likewise notices in

the progress of the individual mind ; and he thinks that every well-grown man is successively religious, metaphysical, and positive, in the course of his spiritual development. And, certainly, every one whose inward experience has been so ardent as to have burned its history indelibly upon the brain, must be conscious that this is true so far as it reaches ; but the word religious must be converted into one which is less august to British ears, and metaphysical into another which is more congruous with the definitions of a better school than Comte's—a school which flourishes in France as well as elsewhere. In general, the first era lasts all the life of the boy. The second waylays the time of youth, when phantasy, fuelled by 'all objects of all sense,' and blown by the hotblast of passion, reigns supreme, and converts the religiosity of more innocent years into lunacy, love, or poetry. The third is the shelter to which youth, harassed and disappointed on every side, betakes itself for refuge, thinking to build a tower of perennial defence.

The whole generalisation of M. Comte's is certainly legitimate to the extent of what it includes. The characteristic of the first era of Man's endeavour upon Nature is faith without facts, faith in conscience being more passionate than either in intellect, or consciousness and sensation ; and it is credulous. The distinguishing feature of the second is a proud trust in intellect ; and being, consequently, comparatively independent either of the facts of consciousness and sensation on the one hand, or of the power of conscience on the other, it is fictitious. The third reposes implicit confidence in consciousness and sensation, or, in one word, in fact ; it sets conscience and intellect quite aside, and, being directly negative of everything that cannot be observed or demonstrated, it is essentially positive in itself. The first is simply emo-

tive ; the second is intellectual and emotive ; and the third is observative, intellectual, and emotive.

The first is not productive of useful art at all. Neither is the second ; but it is propitious to the cultivation and appreciation of the fine arts, as is testified by the statuary and architecture of the Greeks, and by the paintings, statues, and churches of Roman Catholic Italy ; true Roman Catholicism being Christianity in the second stage of its development. The evening, not the morning twilight of an era is always the time when the poets who are to carve, or paint, or sing its condemnation and approaching exolution, come abroad. Homer is a poet of the first period, and Virgil is his echo in a rarer atmosphere. Dante and Milton are religious poets of the second long age, while Shakspeare has sung its operation, in all its multiformity, on the morning of a new day. The positive era has shown no bard, or other kind of poet, comparable with these, although Byron and many a feebler tongue has imbibed its worser influence, and uttered it in gorgeous if ungenial strains. On the other hand, however, this era has created a wonder-working multitude of useful arts. These productive arts go on widening and deepening the domain of the thaumaturgic artisan with so much rapidity, and in directions so unexpected, as to render himself a more and more poetical object every year. Archimedeses, Arkwrights, and Watts, Franklins, Scheeles, and Davys, are its warriors, sword in hand ; while Bacons, Keplers, and Daltons are the council of chiefs under whose orders they conduct the conflict. And if this unresting 'age of tools,' with her manifold influences upon the whole procession of human history, now and ever hereafter, be destined to produce a race of poets worthy of her ancestry and prowess, it is to be inferred from the analogy of the two

preceding eras, that they shall be the children of her maturer days.

It is very easy to expatiate in this antithetical way upon the attendant influences and effects of the three epochs of methodology now under review. Suffice it that, inasmuch as every reader, who could possibly be interested in so diffusive a subject, must possess an epitome of this vast generic history within himself, it is enough to have suggested such an endless and profitable train of reflections.

But M. Comte regards the positive epoch of investigation as absolutely, as well as relatively, the last. For him it is the definitive method of adult manhood. He insists that it is not to be transitional, but consummative in every science. The fact is, that he is a genuine philosopher of the positive type himself. He is the most purely and intensely positive thinker of the age. Clothed, or rather armed, with all the virtues of the scientific era to which he belongs, he is remarkably innocent of its positive errors. His system, according to our thinking, has great deficiencies, but it thrusts no unsightly excrescences into view. There is not anything which he disbelieves; he only does not believe anything until it can be established to the satisfaction of his method of criticism. His denial is passive and not active. He does not exclaim, in proud defiance of all comers, 'There is no God,' like Laplace; but 'Demonstrate the Deity, and I shall record the discovery in my year-book of facts.' His eloquent book shows how keen has been his spiritual experience of its kind. We should infer that he has come wandering thoughtfully through the youngling time of superstitious religiosity of temper, with its superficial but pious theory of the universe; and subsequently found himself mocked by the phantoms, baffled in pur-

suit by the shadows, and wearied by the emptiness of the middle territory with its abstractions, those creatures of the youthful mind, doomed to be their minion in its turn, until he has broken the thralldom of delusion and entered the third era of development, resolved not to believe anything, but to begin at zero, and slowly build up a fabric of irrefragable truth on the solid-looking foundation of observation. This is, of course, a noble step forward, and admirably made, the last position being better than either the second or the first, although they are more pious than its bold, but not impious, front can endure to be thought. Nor is this said unadvisedly ; for this gifted man has at least thought about Nature, and the phenomena of the Universe are the same to him as to another ; so that, if he feelingly assigns them all to matter, what a Divine-seeming thing must matter be to him !

In a word, Auguste Comte has evidently been conscious of no advance in his own history beyond the positive era which he cherishes. This is implied in the proposition he asserts : and it is therefore not wonderful that he has failed to watch and see the dawn of a fourth epoch rising around him in the world. Moreover, just as that eminent *savant* would perfectly understand how one, whom he might know to be still in the second stage of intellectual life, should not comprehend the doctrine of a third, must it be expected that Comte himself shall deny the coming of a fourth. Yet there is a fourth. The third is transitional like its predecessors, and a better is to follow. Not that the method of the positive era is to be overthrown, and all it has discovered to be lost. Nothing is ever lost. The better influences of the superstitious and fictitious eras remain. The good of the positive epoch shall never pass away. That

which is coming on shall homologate and sublime the various right elements of those which have gone before. Its characteristic is that it recognises equally the necessity of faith as the first condition of science, of facts as the objects of science, and of reason as the lawgiver of science, all in order to the creation of a commensurate theory of Nature. It inculcates faith in sensation, and that it is only by such intuitive confidence in the senses that the facts of the material world are to be ascertained ; an equal faith in consciousness, as the ground of all the facts of psychology, in the widest sense of the word ; and a transcending faith in conscience, as referring all things, whether possible or real, to God. It may be called the era of faith. The world of matter known and believed by faith, the world of spirit known and believed by faith, and these made consentaneously one, by that transcending faith in conscience, is the Universe. This tripod is the immovable foundation on which all the sciences are at length to be builded up. Many apostles of this new time have already come and gone ; many are now abroad, but not in the great department of science, which is always behind the philosophy of its age. There is no need of alluding more particularly to these new teachers, since they do not properly belong to the sphere of labour now under survey. But the tripod is the same for all. It represents the synthesis of the three preceding eras, and might be described as an equilateral triangle. Formerly these eras were disjoined, and in antagonism ; but now they are to be bound together in the stablest of figures. The superstition of the first, the fictitiousness of the second, and the scepticism of the third, must all alike be 'swallowed up of victory.' These initial eras were incompatible with pure Christianity, being the 'science falsely so called' of St. Paul ; but science in the

fourth and last, which is the consummation of the times, is the very pole of true religion, and naturally unites with it, and revolves around it like a moon, giving and receiving the kindest sustenance and light. One might even presume to assert that the grand result, towards which it shall be continually swelling forward, is nothing less than the full development of the only true religion; the purely spiritual element of which, and the only element which is essential to the salvation of the world, is embodied and alive in our thrice blessed Christianity. The sciences are no longer to be reconciled with that faith by rationalism, more or less intense, but they are to become one with it through the working of their own inherent and inextinguishable tendencies. Why, a true and comprehensive theory of the universe, such as has been indicated above;—the world of sensation, and the world of consciousness, turned into one by faith in Jehovah, and in every revelation He has given, or shall give;—such a theory, initiated by faith, elaborated by inexorable positive research, and finding its apotheosis in faith so ever present and unfailing as always to inspire the will, were surely Christianity, as it is designed to become by its Divine author. But have we no Christianity till then? Heaven forbid we should be so misunderstood. Consider a moment. For any the most microscopical of theories, it is by no means necessary that all the details, which can be brought within its scope, be incorporated in it at once. The new facts fall harmoniously into their places when they arrive. A genuine theory is a germ of life, and gradually clothes itself with an expanding framework of organisation. It has shown itself to be such in almost all the sciences. It is surely to be the same, only with infinitely more emphasis, with that theory of the universe, which, believed by no irrational faith, is to

become the full-grown religion of mankind. The theory is begun whenever the largest proposition is established on the right foundation. Those old traditionary records which Moses, guided by the inspiration of God, has put before the national history of the Hebrews in the book of Genesis, are, so far as literature is concerned, the foundation of the great theory now contemplated: GOD MADE, AND IS OVER ALL. Then a line of inspired seers predicted, and at last Jesus Christ affirmed and transacted the second capital fact of the theory: and the proposition of the atonement was laid down. Minor, but still principal elements, succeeded in their order; and the apostles completed the first round of the succession of circles that are to follow. The succeeding circles shall undulate around Revelation as a propagative centre of force, wave succeeding wave, not in years but in great centuries of research. The idea of positive science, nascent at the revival of letters in modern Europe, and now in the process of its completed manifestation, has hitherto been disrupted and out of tune; but it begins to tremulate into concentric harmony with the great interior sphere of truth at last. All the future achievements of the mind of Man shall only magnify this expanding music of the universe, and swell the incontinent diapason, until Science the Ideal shall murmur back the loud and lofty echo of Nature the Real:

THE EARTH IS THE LORD'S, AND THE FULNESS THEREOF.

THE HUMANITIES OF SCIENCE.

[THE following Sonnets constitute all Dr. Brown was enabled to complete of a work designed by him under the title, 'The Humanities of Science.' The scheme of it is sufficiently explained by that section now presented to the public: to exhibit the historical development of each of the sciences as is here attempted on behalf of Astronomy, through a series of connected Sonnets descriptive of the successive nations or men through whom that development has been wrought out. The nine Sonnets entitled 'The Overture,' were intended as an introduction to the whole.]

THE OVERTURE.

1.

THE sonnet once was set apart for love;
The love of beauty's shrine in woman's eye,
The love of truth and goodness in her sigh,
The love of All in her, excelling dove!
For woman stood embodied Peace above
The wayward life of those Italian singers,
Who used this measure first. Less amorous bringers
Of heavenlike forms from out the tangled grove
We live in; Milton, Wordsworth, and some more,
Have stolen the gracious vase, and filled it high
With far more various wine than lover shy,
Dante or Petrarch, ever dared to pour.

Ah! say not stolen; the thing was theirs before:
All poetry is love's and lover's lore.

II.

SHAKSPERE, the sovran lord of English speech,
Who shook his lance, and stretched it every way
Where passion dies and folly has its day,
Did not disdain the sonnet, nor to teach
How one long tale of loves might overreach
From sonnet unto sonnet, till the stream
Should grow oppressive with its rush of pain,
And make the reader all but not beseech
The sonnet-song, or rather dirge, to cease.
They say those stanzas hold his dearest blood,
Like magic cups they run an endless flood,
Each is so full as not to brook decrease.

Drink into one, O reader ! there's another :
The man that overfilled them was thy brother.

III.

HIGH Spenser too, the knight of knights I ween,
Shedded his manly love's triumphing story ;
Its prayers, its strifes, its proud despairs, its glory,
And all its sweet contests, from morn to e'en :
He poured it all, I say, within a pomp
Of shapely sonnets, cups of hypocrene ;
And was it not a banquet for a queen ?
'Twas eke this stanza's quaint revolving pomp,
Wherein he told the tale of Rome's decay,
And painted visions complete one by one, \$. .
Yet each sustaining each in long array.
A gem, an urn, a heav'nly star, the sun,
A lordly tree, a lion or a man,
May dwell apart in some majestic plan.

IV.

COME then, my Amoret, prick forth with me,
And in a flight of sonnets let me show
How much of love there is in things below.
My modest Dian, chase me while I flee
Fleetly from earth to air, from air to sea ;
And with unwetted wing ascend to heaven,
Whence coming down we shall, if strength be given,
Enter the Hades of the world and see
How time hath built it up for love and thee.
Then may we plunge to still profounder deeps,
Atomic centres where hush'd Nature keeps
Her inmost, most unspeakable degree
 Of motherly reserve. Away with fear !
 Thou canst not lose the way, for love is near.

V.

LONG have I studied Nature, as thou know'st,
First as my queenly mistress, and supreme ;
Then as my beauteous foe, although a dream ;
Now as my equal sister and my boast.
My sister now, my all-confiding host,
Her various self my various entertainment :
But doom'd, they say, to shrivel and be lost ;
A thing beyond the eye of ascertainment,
And therefore all unwelcome to my soul.
She may be younger, for my first-born brother,
My joint-heir said, who ne'er traduced another,
I AM BEFORE THE WORLD BEGAN TO ROLL !
 O Jesus, keep my trembling faith above !
 My sister almost hurts me with her love.

VI.

YOUNGER or older than the soul, alas !
Be this illustrious creature doomed to die ;
Nevertheless 'twere wondrous well, thought I,
'Twere passing well to know her ere she pass,
To know her in her ends and in her cause.
'Twere passing well to know the One she is,
The various type of Him who made her His ;
'Twere passing well to know her in her laws,
Her true obedience spite of seeming flaws,
Her steadfast heart aneath capricious shows ;
'Twere passing well to know her how she grows,
Her coming age from what her childhood was :
 'Twere wondrous well to learn her loving lore,
And tell her then I knew it all before !

VII.

HER loving lore, for Nature never stood
Around the soul to crush him in her arms ;
Her hundred outstretch'd hands have no alarms,
She holds them forth to do her darling good ;
Her hundred speaking eyes did never mean
To overawe her wayward foster-child.
Mild was Briareus, ocular Argus mild,
And she, their mother, wears a gracious mien.
'Twas ne'er her will to thwart me, for I've seen
My proudest bidding done with willing hand :
Thy signs, she said, were hard to understand !
She is not deaf, but we are dumb, I ween.
 We beckon and we beckon from our tents,
At last she understands us and consents.

VIII.

FAR be the thought that Nature only serves,
A gnome, a willing drudge, a pleasant slave.
Ten thousand curses on the tyrant knave ;
Ten thousand curses all the wretch deserves,
Who bids her come and go because she's kind,
Or seeks her favour only for the gain !
She does his will, perhaps, but strikes him blind.
Obedient to her Lord, she mixes pain
In every cup of pleasure he commands.
Drink if he choose—he quaffs his soul away ;
She cannot choose but curse him and obey.
Severe yet mild, like Nemesis she stands
 Upon her 'eye for eye, and tooth for tooth.'
 No man escapes her justice long, forsooth !

IX.

FAR otherwise she helps the gentle mind.
I heard her sigh, one summer's eve, to such :—
O son of man, it doth rejoice me much
Within thy troublous heart this love to find.
Unequal children we, of common sire,
But thou hast that to do I cannot know,
Much to endure, acquire, enjoy, bestow.
Within thee burns an all-celestial fire :
O see it nor destroy thee, nor expire !
Come, let thy sister serve thee while she can,
Tend thou the heavenly flame, and tune a lyre.
Come, let her teach thee all becomes a man ;
 For thou an angel art beneath thy seeming—
 Ah ! I shall never see thy glory beaming !

ASTRONOMY.

THE HEBREW.

WHEN David or his sire, 'tis all the same,
Sate long ago upon a purple hill,
Watching his sinless flock from nightly ill,
The golden sun went down ; the pale moon came,
A slender crescent woven of silver flame ;
And one by one at first, then ten by ten,
The stars slipp'd out, and in, and out again,
Until a thousand prank'd the sapphire frame.
Some red, some blue, and others like the moon,
And also some like little suns at noon,
He knew them well, although unknown by name ;
They shone all night for love, and not for fame.
Lord, what is man, he cried, that such a choir
Should overwatch him thus with eyes of fire !

THE PERSIAN.

DRUNK with the wine of life, and blind with leaves
He pluck'd in Eden to adorn his head,
The shepherd soon forgot his Lord and said,
'I cannot see my God . . . the soul deceives.'
He staggered on amid the tawny sheaves ;
Grape-clusters ruddy, and sleek cattle bred
Among the corn and wine, his senses fed
Unto intoxication, not his soul.
But night still came and came with cooling breath,
And sighed, *'Look up, O red-eyed Life-in-death !'*
Prostrate and fond, he worshipped HER, and stole
A slave's quick glances at the glories spread
In sphere sublime above his spherul head.
Man first forgets, then doubts, then misbelieves.

THE GREEK.

At length two wand'ring Angels reached the ground,
And dwelt like gods among the Dorian race.
IMAGINATION wing'd, of radiant face,
With ART, well-skilled all boundless things to bound,
And mould them into shapes poor Man could love.
The twain transformed the world into a poem !
And so it is, a piece without a proem ;
But those light-hearted Greeks the heav'ns above,
With nought but festive grace, did compass round.
They sported with the Signs, and called them names ;
For them the Sun herculean footsteps trod,
The sky a play-ground and the seasons games.
O Greece ! I loved thee dearly, till I found
Thine arts did but conceal an Unknown God !

PTOLEMY.

I.

BUT men behaved to think as well as play,
And Ptolemy the Great expressed his thought
In tones so Orphic, clear, and strong, that naught
Could stand against his word for many a day.
' Still stands the earth,' he cried, ' and well she may,
Her central caves the home of sin and pain,
For red Hell glows within her black domain.
Round her revolves the Moon with watery ray,
The changeful star of mothers and the chase.
Encircling both Mercurius runs his race,
The friend of Genius, as the Magi say.
Ambiguous Venus, dear to me her face,
Doth circumvolve the three with glowing poles,
Sweet queen of hearts, but not the queen of souls !

II.

' BEYOND this moony triad moves the Sun,
Osiris, Horus, Vishnu, Phœbe's God ;
Stout Hercules among the Signs abroad,
Achieving tasks again to be begun ;
Apollo, soul of beauty to the fair ;
Delios, star of wisdom to the wise ;
Sole monarch of the day, arise, arise,
Inscribe thy burning track upon the air,
And weave thy dazzling sphere around the world !
True centre thou of all the crystal scheme ;
'Tis liker God to never rest than dream.
Mars, Jove, Saturnus, outside thee were hurled ;
They, too, must share thine all-inspiring fire :
Space is the womb of things, and thou the sire.

III.

‘ THIS complex orb, one animated thing,
 The homely world we live in and its stars,
 At peace within itself in spite of Mars,
 Is next surrounded by a far-drawn ring
 Of glorious Constellations and of Signs ;
 Révolving ever vast, and swift, and still,
 The mind of mortal man to overfill
 With thoughts of wonder, far beyond the lines
 Of geometry to measure or compute.
 Enclosing all, O heavens, two starless spheres !
 Swifter than motion one ; the other fears
 To move at all, for God Himself, and mute
 Angels, and holy souls, move there without alloy :
 ’Tis the Empyrean, boundless house of Joy !’

KOPERNIK.

O BEST-ENDOW’D and bravest Pole of Poles !
 Stupendous was thine insight into things :
 And things celestial, too ; though stars, not souls.
 Thine more than any man’s, the skill that brings
 The truth that is from out the truth that seems.
 How free thy will, how plastical thy mind
 With love-like bands of light the sun to bind,
 A wand’ring joy till then in all our dreams !
 But bind in honour, as a King is bound,
 By holy law, to bless, sustain, and rule.
 No wonder thou wert crush’d instead of crown’d ;
 The church was frightened, and abash’d the school.
 O for another error-quelling Mars,
 To range the world of souls, as well as stars !

KEPLER.

TEUTONIC Kepler, spurning due control,
 Pythagorean wild, harmonious soul!
 To what strange conch didst thou apply thine ear,
 And catch the music of the solar sphere?
 Or, was the sphere itself that mystic shell,
 Brought hither from the ocean-shore divine,
 Still crooning o'er its secret like a spell,
 To other ears a hum, a song to thine?
 Rapt in harmonic ratios, laws, and rhymes,
 Thou couldst not watch the turns, nor keep the times
 Of life prosaic, and therefore thou wert poor;
 Thy bread uncertain, thine ambrosia sure:—
 This low-lived world might lift her head again,
 Could she but rear a race of such poor men!

NEWTON.

I.

KOPERNIK fix'd the Sun, the work began;
 And Kepler raised the time-infolding plan:
 But there was wanted one, of loftier fame,
 To round the wondrous dome; and Newton came.
 From English fields he went, with British eyes
 And British hands, to join the vast emprise.
 'Twas his to bring to Reason, facts and signs,
 And found the System on eternal lines.
 Sublime invention, understanding clear,
 An angel's abstract thought and godly fear,
 Industrious toil from glorious year to year,
 For years are counted days in such a sphere;—
 These were the spells wherewith this builder wrought:
 Creation owns the rights of patient thought!

II.

O NEWTON, I adored thee when a boy ;
My father's hero thou, and I his joy !
Impetuous Chalmers, simpler than a child,
Had loudly told us thou wert meek and mild,
Patient and humble, very pure and good,
Within our holy place thine Image stood,
More like a blessed God than needy man ;
Another kind of Christ ; a Christian Pan ;
Father and son, we wept because of thee,
For very joy to think what man could be !
My fellow-student gone, I learn'd betimes
Thou hadst thy grievous faults, they were not crimes.
Without them, would have been to be Divine ;
But with them, thou art more mankind's and mine.

III.

THEY say thou hadst thy faults. I cannot tell,
For all I know is this, This world were hell
To certain souls, if thou and men like thee
Had never eyed the fruit, nor clomb the tree,
Of bitter-sweet and poison-stain'd delight.
My mates and I were in a woful plight,
Were our companions all ignoble men ;
But, as it is, we raise our eyes again ;
Not to the fruited boughs, but t'wards the throne
Of Him who sits in purity, alone.—
Remote, I see thee scan the Holy One,
As erst thou gazedst on His type, the sun.
Nearer and nearer press, immortal child ;
Unlike the sun, His nearer ray is mild !

HERSCHEL.

I.

BUT who is this that spurns the solar day,
And treads with buoyant feet yon ether thin?
An eye outside his eye, and one within,
The dim of night grows clear before his ray.
Three-sighted mortal! Is the Milky Way
A single thing?—a crystal made of stars,
A separate gem among celestial spars;
Within whose glittering bounds our earth doth play
A tiny part, and like an atom shines,
Yet seeks, and so runs round a sparkling dot?
Poor little world, and poorer still our lot,
Were Reason not a Power beyond the suns :—
Eternal thanks to Herschel and to Thought,
The widening reach of sense the Soul outruns.

II.

FULL-HEARTED swimmer through the ambient main!
Our firmament behind, one billow past,
The starry surge will never yield a last.
Onward they sound for ever, their refrain
Not to be caught or written down. In vain
Shall man, ay, or archangel, struggle o'er
Their gleaming crests to find a further shore.
Coast there is none, nor sky, nor pleasant rain;
No usual limit, no accustomed thing;
Nothing but glory, glory poured until
Infinity is full. Back, venturous Will,
Back to our homely rock ;—and with thee bring
This word of truth from space, for me to sing :—
'Tis all too little yet poor Man to fill!

LAPLACE.

WHENCE sprang fair Earth and all her busy mates ?
The old Sun flung them from his blazing sides,
When molten rock did run in ebbs and tides.
So sang Laplace : but what of solar dates ?
The Sun began to be, conjecture states,
When cooling chaos was a fiery steam,
And just began with dreadful dewes to teem.
The awful drops revolved at maddening rates,
Drops in that mist immense and big with fates,
But dreary burning-oceans unto thought.
Our Orb of Day was one of these, and sought
His proper sphere of toil, our bard relates.
Industrious Heavens, how bravely ye have wrought
This star-lit home for Man, who gave you nought !

AN AFTERTHOUGHT.

THERE'S no repose within this optic sphere ;
The world is like the soul, though not so fair.
The young moon waxes, wanes, and follows where
Dear Earth is hasten'd in her fond career ;
Unresting planets run with love and fear ;
Tormented comets leave their distant lair ;
Imperial Sol himself is glad to share
The common fate : he wanders wide, I hear,
Within the Milky Way. It might appear
That all the firmaments revolve afar,
Circling the Throne of Him, whose only bar
Is his own making ? Nay, that Heaven is near :
God is the present soul of every star,
His central home is here as well as there !

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